Vol. XVI, Part IV August, 1946

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority

of

The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 3 or 5s.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE GOVERNMENT OF INDIA PRESS, CALCUTTA, INDIA,
1947

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(August 1946)

The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

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,,	72	,, 4	,,	Gotting	,,	Gothing
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ORIGINAL ARTICLES

COMPARATIVE STUDIES ON INDIAN SOILS

VI. THE DEPTH DISTRIBUTION OF WATER-SOLUBLE SALTS IN THE PROFILE

By U. N. SEN GUPTA, ABHISWAR SEN, A. C. UKIL and B. VISWA NATH

Imperial Agricultural Research Institute, New Delhi

(Received for publication on 21 March 1944)

ONE of the chief agencies in the differentiation of the materials within a soil horizon is the soil solution. A study of the nature of the soil solution, therefore, would yield valuable information about the soil forming processes. Zakharov [1906] discussed the significance of the soil solution for the different processes of soil formation and established its characteristic properties for the various soil types. Though soil extracts prepared in the laboratories could never correspond to soil solutions existing under natural condition, Sigmond [1938] found that water extracts might be very instructive in the chemical characterization of a soil.

Generation of soluble salts in a soil depends mainly upon the parent material. It is, however, largely affected by the climate-vegetation complex. The dependency of the composition of soluble salts on the parent material may sometimes be masked by the effect of climate which leaves its impress upon the concentration rather than the composition of the salts. Arid regions are always characterized by higher soluble salt content than the humid regions. This is rather unexpected as with more rainfall more soluble salts are expected to form in the soil. McCool and Millar [1920] working with soils from widely different climatic regions, found that amounts of salts generated by washed arid region soils were actually smaller than those from soils of humid regions. With low rainfall and high temperature salts try to accumulate at the surface layers of arid region soils while they go down in humid soils with higher rainfall. The resultant effect is the high concentration of soluble salts in arid regions and much less soluble salt content of the soils of humid or perhumid regions. Thus effect of climate on a soil is more easily reflected on the soluble salt content than on any other factor. Distribution of the salts along the profile is thus expected to be uneven depending on the nature of the horizon and its depth from the surface. Depth distribution of water soluble salts in the profile is, therefore, of importance in assessing the effect of climate on soils.

MATERIALS AND METHODS OF ANALYSIS

Soils reported in the paper were all virgin, collected from different parts of India for the purpose of a preliminary soil survey.*

In estimating the soluble salt content of a soil, the ratio of soil to water is an important consideration. Soil water ratio does not affect the solubility of chloride and nitrate ions but it is an important factor in regard to carbonate and bicarbonate ions, besides the effect of soil water ratio on the relative proportions of cations and anions due to base exchange. In our determinations the widely adopted ratio of one of soil to five of water was adopted.

Extraction of soluble salts. One hundred grams of soil were treated with 500 c.c. carbon dioxide-free distilled water and left for 24 hours with frequent shakings. The soil water suspension was then filtered through Pasteur Chamberland Filter.

Total salts, calcium and magnesium. One hundred cubic centimetres of the extract was taken in a weighed platinum basin and evaporated on water bath till dry. It was then dried in an air oven kept at 105^{0}C. and cooled in a desiccator and weighed to a constant weight. The residue was total solids.

The residue after the determination of total solids was ignited and redissolved with dilute HCl. The solution was treated with excess ammonia and after acidifying the liquid with a few drops of acetic acid calcium was precipitated as oxalate by boiling with 1 gm. of ammonium oxalate. Calcium was estimated from the precipitate in the usual way.

*Descriptions of soils are given in part I of this series=*Indian J. agric. sci.* **14**, 333-44

The filtrate and washings from above were concentrated, ammonified and treated with sodium phosphate. It was left for 24 hours. The precipitate of magnesium ammonium phosphate was washed, dried and ignited to magnesium pyrophosphate and weighed.

Carbonate, bicarbonate and chloride. Another 100 c.c. aliquot was taken and titrated with N/50 H_2SO_4 with phenolpthalein as indicator. Methyl orange was then added and titration was continued for bicarbonate. After neutralization, chloride was estimated by titration with N/50 $AgNO_3$ with $K_2C_rO_4$ indicator.

Sulphate. Sulphate was weighed as $BaSO_4$ after precipitation from an acidified 100 c.c. aliquot by boiling with $BaCl_2$.

Potassium. Another 100 c.c. aliquot was evaporated to dryness, treated with HCl and 1 c.c. of H_2PtCl_6. The residue was washed and weighed as K_2PtCl_6.

Sodium. Sodium was obtained by difference. The acids and available bases were combined to form salts after the method of combination followed by Leather [1902]. Excess acid was assumed to be combined with sodium.

Nitrate. Forty grams of soil were shaken with 200 c.c. of water with 1 gm. of $CaSO_4$ to aid filtration and filtered through an ordinary filter paper. An aliquot was evaporated on a porcelain basin on a water bath and the nitrate was determined by the phenol disulphonic acid method. Chlorides, when present in large amounts, were removed by silver sulphate.

Classification of Indian soils on the basis of soluble salts

The results of analysis are given in the appendix as percentages on air-dry soil.

The analyses of aqueous extracts of the soils of the profiles have given useful indications regarding anions and cations which play an important role in the soil solution. Striking differences which indicate water and salt movement under climatic influences, have been noticed. On the basis of the nature and concentration of water soluble salts at different depths five main groups may be formed. In the profiles of the first group sodium and chlorine predominate ; in the second the sulphate radical is either very low or absent ; the third group is characterized by the predominance of either Ca or Na or SO_3 or Cl ; the fourth is characterized by very high salt content, while the fifth contains very low amount of salts.

On the basis of relative concentrations also, five main groups may be differentiated. Thus there are (i) profiles in which the concentration of soluble salts is highest at the surface and lowest at the bottom ; (ii) profiles in which the concentration is highest at the surface but lowest somewhere in the middle of them ; (iii) profiles in which the concentration is highest somewhere in the middle, but lowest either at the surface or at the bottom ; (iv) profiles in which the concentration is highest at the bottom, and lowest either at the surface or somewhere in the middle ; and (v) profiles in which the concentration of water-soluble salts is more or less uniform throughout and the total quantities of them are also very low.

Group (iv) can be further subdivided into two groups (*a*) one in which the total quantity of water-soluble salts is very low, and the difference between the highest and the lowest is not considerable ; and (*b*) the other in which the total quantity of water-soluble salts is very high, and the difference between the highest and the lowest is also very great.

Peshawar, Mianwali and Taliparamba come under the first group. In Peshawar profile sodium chloride has concentrated itself into the first two feet from the surface, there being practically nothing of it below this depth. Calcium and magnesium are proportional to total soluble salts in all the depths. The significant point of difference between this profile and the other two profiles (Mianwali and Taliparamba) of this group is that sodium chloride, which concentrated itself into the first two feet of the former, was distributed throughout in the latter.

The second group comprise Gurdaspur, Jorhat, Rangpur, Ranchi, Karachi and Nagpur. The amount of total salts in these profiles, with the exception of Karachi, is not high. Chloride, the preponderating radical, is proportional to the total soluble salts. Sulphate is low and is not present in all the profiles. There is no nitrate in any of them. Karachi, however, is much richer in soluble salts than other profiles of the group and contains nitrate and enough of sulphate. Its composition shows closer proximity to group III. Chloride is not proportional to total soluble salts in this profile.

Lahore, Lyallpur, Kangra, Padrauna, Makrera, Chinsura, Sylhet, Haripur-Hazara, Tabiji, Koilpatti, Karimganj, Hagari, Sāmalkot and Mirpurkhas fall into the third group. They are mostly rich in calcium and sodium. Some of them are rich in sulphate, and some in chloride. Those rich in sulphate are found to contain nitrate also, whereas those rich in chloride do not generally contain any nitrate. Chlorine is proportional to the total soluble salts in most of the cases. In Hagari and Samalkot, sodium is the preponderating base and in Mirpurkhas potassium. Padrauna and Mirpurkhas deviate slightly from the other profiles of the group in as much as the lowest concentration of salts in them is in the middle instead of being either in the surface or at the bottom.

Group (iv, a) consists of Akola, Labhandi, Waraseoni, Coimbatore, Nandyal, Anakapalle and Berhampur. Sodium bicarbonate is the principal salt in Akola, Labhandi and Nandyal and calcium bicarbonate in Waraseoni and Coimbatore. Nandyal is richer also in sodium sulphate and sodium chloride. The composition of Anakapalle and Berhampur profiles bear resemblance to that of group (iv). Anakapalle is rich in calcium bicarbonate and sodium chloride, whereas Berhampur is rich in potassium bicarbonate and sodium chloride. There is no nitrate in any of them except Nandyal which contains some in the first two feet only.

Group (iv, b) consists of Sakrand and Padegaon. They are the richest of all as far as soluble salts are concerned, so much so that the amount of salts at their lowest depth (5 ft.) are enough to make a soil sterile. In the case of Sakrand, the quantities of sodium and chlorine fall at 5 ft., although there is a definite increase in the total soluble salts. This is not the case with Padegaon. All other radicals, except HCO_3 which has fallen towards the end in both the profiles, have followed more or less the course of total soluble salts.

Shahjahanpur, Powerkhera, Indore, Sirsi, Surat, Chandkhuri, Kheri-Adhartal, Kharua, Dacca, Pusa and Delhi come under group V. These are found to contain mostly calcium bicarbonate, Sirsi being perhaps the only exception. There is no nitrate in any of them except Pusa. They are the poorest of all in total soluble salts.

The principal salt in Chandkhuri, Kheri-Adhartal, Kharua and Dacca is either calcium bicarbonate or sodium chloride.

Summary

On the basis of the nature and concentration of soluble salts at different depths, Indian soils may be classified into five main groups.

Group I. The group is characterized by the predominance of Na and Cl. The concentration of soluble salts in such a profile is highest at the surface and lowest at the bottom.

Group II. Sulphate is very low; soluble salts are highest at the top, not lowest at the bottom.

Group III. It is characterized by predominance of either Ca or Na or SO_3 or Cl; concentration of salts is highest neither at the surface nor at the bottom.

Group IV. This group is generally characterized by very high salt content, the concentration being highest at the bottom.

Group V. This group is characterized by low content of soluble salts which are distributed more or less evenly throughout the profile.

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Appendix

The water-soluble salt contents of soil profiles

Depth in ft.	$Ca(NO_3)_2$	$CaCO_3$	$Ca(HCO_3)_2$	$CaSO_4$	$CaCl_2$	$Mg(HCO_3)_2$	$MgSO_4$	$MgCl_2$	$KHCO_3$	K_2SO_4	KCl	$NaHCO_3$	Na_2SO_4	NaCl	Total solids
1. *Peshawar*															
0—1	..	0·0054	0·0601	..	..	0·0110	0·0288	..	..	0·0144	..	..	0·0076	0·0351	0·175
1—2	..	..	0·0405	0·0135	..	..	0·0293	0·0003	..	..	0·0046	..	..	0·0369	0·145
2—3	..	..	0·0344	..	..	0·0056	0·0065	0·0127	..	..	0·0025	..	..	..	0·070
3—4	..	..	0·0324	..	..	0·0048	0·0052	0·0142	..	..	..	..	..	..	0·060
4—5	..	..	0·0243	..	..	0·0094	0·0058	..	..	..	..	..	0·0023	0·0088	0·050
10. *Mianwali*															
0—1	0·0122	..	0·0143	..	..	0·0033	..	..	0·0029	0·0093	0·0006	..	..	0·0244	0·090
1—2	0·0053	..	0·0251	..	..	0·0060	0·0004	..	..	0·0036	..	..	0·0026	0·0146	0·050
2—3	0·0058	..	0·0206	..	..	0·0033	..	..	0·0021	..	..	0·0062	0·0061	0·0102	0·043
3—4	0·0007	..	0·0235	..	..	0·0033	..	..	0·0010	..	..	0·0039	0·0046	0·0088	0·035
4—5	..	..	0·0182	..	..	0·0033	..	..	0·0021	..	..	0·0026	0·0030	0·0117	0·033
51. *Taliparamba*															
0—1	..	..	0·0116	0·0029	0·0008	..	..	0·0064	..	..	0·0046	..	..	0·0140	0·070
1—2	..	..	0·0162	..	..	0·0011	..	0·0100	..	..	0·0046	..	..	0·0134	0·060
2—3	..	..	0·0142	..	..	0·0003	..	0·0105	..	..	0·0046	..	..	0·0113	0·050
3—4	..	..	0·0101	..	..	0·0065	..	0·0022	..	..	0·0031	..	..	0·0169	0·045
4—5	..	..	0·0081	..	..	0·0031	0·0013	0·0033	..	..	0·0031	..	..	0·0154	0·033
7 *Gurdaspur* ($Mg(NO_3)_2$ in the $Mg(HCO_3)_2$ column)															
0—1	0·0005	..	0·0290	0·0036	..	..	0·0022	0·0130	..	..	0·0061	..	..	0·0136	0·084
1—2	0·0181	..	0·0145	..	..	0·0069	0·0051	0·0043	..	..	0·0006	..	..	0·0293	0·084
2—3	..	..	0·0145	0·0072	0·0035	..	..	0·0115	..	..	0·0030	..	..	0·0039	0·060
3—4	0·0041	..	0·0145	0·0035	0·0003	..	..	0·0090	..	..	0·0024	..	..	0·0153	0·061
4—5	0·0151	..	0·0116	0·0005	..	..	0·0054	0·0046	..	..	0·0041	..	..	0·0228	0·076
35. *Jorhat* ($Mg(HCO_3)_2$)															
0—1	..	..	0·0087	0·0017	0·0023	..	..	0·0226	..	..	0·0006	..	..	..	0·071
1—2	..	..	0·0029	..	0·0050	..	..	0·0087	..	..	0·0029	..	..	0·0110	0·050
2—3	..	..	0·0058	..	0·0030	..	..	0·0052	..	..	0·0012	..	..	0·0173	0·052
3—4	..	..	0·0058	..	0·0002	..	..	0·0080	..	..	0·0015	..	..	0·0107	0·037
4—5	..	..	0·0041	..	..	0·0016	..	0·0046	..	..	0·0031	..	..	0·0138	0·040
39. *Rangpur*															
0—1	..	..	0·0081	..	..	0·0035	..	0·0055	..	..	0·0076	..	..	0·0070	0·046
1—2	..	..	0·0093	..	0·0019	..	..	0·0039	..	..	0·0038	..	..	0·0100	0·037
2—3	..	..	0·0053	..	0·0019	..	..	0·0039	..	..	0·0095	..	..	0·0006	0·028
3—4	..	..	0·0040	..	..	0·0011	..	0·0032	..	..	0·0019	..	..	0·0062	0·017
4—5	..	..	0·0053	..	0·0019	..	..	0·0078	..	..	0·0020	..	..	..	0·023
22. *Ranchi*															
0—1	..	..	0·0087	..	0·0079	..	..	0·0053	..	..	0·0033	..	..	0·0523	0·093
1—2	..	..	0·0101	..	..	0·0013	..	0·0016	..	..	0·0033	..	..	..	0·016
2—3	..	..	0·0116	0·0021	..	..	0·0032	0·0072	..	..	0·0049	..	..	0·0283	0·068
3—4	..	..	0·0174	..	0·0033	..	..	0·0090	..	..	0·0074	..	..	0·0140	0·064
4—5	..	..	0·0116	0·0029	0·0130	..	..	0·0061	..	..	0·0044	..	..	0·0255	0·087

							12. Karachi								
0—1	0·0158	..	0·0203	0·0204	0·0460	..	..	0·0278	..	..	0·0484	..	..	0·0872	0·320
1—2	0·0043	..	0·0260	0·0051	..	..	0·0108	..	..	0·0282	0·0036	..	..	0·1143	0·190
2—3	0·0016	..	0·0231	0·0658	..	..	0·0243	..	..	0·0251	..	..	0·0312	0·0995	0·270
3—4	0·0009	..	0·0231	0·0919	..	..	0·0297	..	..	0·0251	..	..	0·0053	0·1097	0·305
4—5	0·0017	..	0·0231	0·0437	..	..	0·0108	..	..	0·0106	0·0071	..	..	0·1144	0·235
							24. Nagpur								
0—1	..	..	0·0425	..	..	..	..	..	0·0010	..	..	0·0121	0·0015	0·0146	0·070
1—2	..	..	0·0303	..	..	0·0092	0·0006	..	..	0·0009	..	..	0·0017	0·0088	0·050
2—3	..	..	0·0243	..	..	0·0131	..	..	0·0010	..	..	0·0039	0·0015	0·0117	0·048
3—4	..	..	0·0182	..	..	0·0131	..	..	..	..	..	0·0170	0·0015	0·0088	0·048
4—5	..	..	0·0243	..	..	0·0099	..	..	0·0031	..	..	0·0179	0·0015	0·0102	0·055
							3. Lahore								
0—1	..	..	0·0243	..	..	0·0066	..	..	..	0·0027	..	0·0153	0·0024	0·0073	0·058
1—2	0·0087	..	0·0258	..	..	0·0066	..	..	..	..	..	0·0107	0·0305	0·0351	0·115
2—3	0·0224	..	0·0405	0·0153	..	..	0·0135	..	..	0·0009	..	..	0·0586	0·0761	0·283
3—4	0·0112	..	0·0434	0·0069	..	..	0·0135	..	..	..	..	..	0·0803	0·0673	0·230
4—5	0·0006	..	0·0405	0·0198	..	..	0·0135	..	..	..	..	..	0·1416	0·0219	0·245
							9. Lyallpur								
0—1	..	..	0·0318	0·0021	..	..	0·0020	0·0049	..	..	0·0146	..	..	0·0060	0·060
1—2	0·0033	..	0·0318	0·0317	..	..	0·0081	0·0064	..	..	0·0077	..	..	0·0036	0·105
2—3	0·0342	..	0·0231	0·0467	0·0033	..	..	0·0171	..	..	0·0061	..	..	..	0·183
3—4	0·0658	..	0·0202	0·0131	0·0015	..	..	0·0107	..	..	0·0031	..	..	..	0·165
4—5	0·0421	..	0·0202	0·0102	0·0089	..	..	0·0107	..	..	0·0046	..	..	..	0·150
							8. Kangra								
0—1	0·0005	..	0·0203	0·0043	0·0070	..	..	0·0082	..	..	0·0041	..	..	0·0015	0·072
1—2	0·0110	..	0·0174	0·0092	..	..	0·0007	0·0071	..	..	0·0046	..	..	0·0148	0·106
2—3	..	..	0·0174	0·0061	0·0104	..	..	0·0102	..	..	0·0059	..	..	..	0·105
3—4	..	..	0·0174	0·0075	0·0059	..	..	..	..	..	0·0046	..	..	0·0158	0·077
4—5	0·0192	..	0·0174	0·0030	..	..	0·0043	..	..	0·0053	..	..	0·0004	0·0261	0·097
							19. Padrauna								
0—1	..	..	0·0492	0·0044	..	..	0·0012	0·0050	..	..	0·0099	..	..	0·0270	0·091
1—2	..	..	0·0280	..	..	..	0·0056	..	..	..	0·0015	..	..	0·0049	0·030
2—3	..	..	0·0290	0·0054	0·0032	..	..	0·0086	..	..	0·0109	..	..	0·0545	0·103
3—4	..	..	0·0231	0·0010	..	..	0·0009	0·0014	..	..	0·0073	..	..	0·0159	0·040
4—5	0·0009	..	0·0214	..	..	0·0083	..	..	0·0013	0·0074	..	..	..	0·0158	0·051
							33. Makrera								
0—1	0·0053	..	0·0190	..	..	0·0120	..	..	0·0208	0·0020	..	..	0·0058	0·0198	0·080
1—2	0·0013	..	0·0319	0·0129	..	..	0·0037	0·0127	..	..	0·0114	..	..	0·0347	0·119
2—3	..	..	0·0319	..	0·0321	..	..	0·0235	..	..	0·0076	..	..	0·0947	0·243
3—4	..	..	0·0319	0·0439	..	..	..	0·0235	..	..	0·0019	..	..	0·1974	0·321
4—5	..	..	0·0319	0·0106	..	..	0·0396	..	..	0·0089	..	..	..	0·1733	0·262
							40. Chinsura								
0—1	..	..	0·0162	..	..	0·0010	..	0·0072	..	..	..	..	..	0·0077	0·051
1—2	..	..	0·0320	..	..	..	0·0025	0·0058	..	..	..	..	..	0·0126	0·060
2—3	..	..	0·0372	0·0028	0·0027	..	..	0·0117	..	..	0·0019	..	..	0·0159	0·094
3—4	..	..	0·0372	0·0014	0·0066	..	..	0·0117	..	..	0·0057	..	..	0·0072	0·080
4—5	..	..	0·0194	0·0014	0·0101	..	..	0·0078	..	..	0·0038	..	..	0·0097	0·078
							37. Sylhet								
0—1	..	..	0·0058	..	0·0002	..	..	0·0074	..	..	0·0010	..	..	0·0058	0·039
1—2	..	..	0·0027	..	0·0010	..	..	0·0039	..	..	..	..	..	0·0125	0·036
2—3	..	..	0·0027	..	0·0037	..	..	0·0039	..	..	0·0057	..	..	0·0215	0·050
4—4	..	..	0·0027	..	0·0037	..	..	0·0039	..	..	0·0076	..	..	0·0365	0·074
3—5	..	..	0·0040	..	..	0·0011	..	0·0031	..	..	0·0038	..	..	0·0119	0·030

APPENDIX—*contd.*

The water-soluble salt contents of soil profiles

Depth in ft.	Ca (NO3)2	CaCO3	Ca (HCO3)2	CaSO4	CaCl2	Mg-(HCO3)2	MgSO4	MgCl2	KHCO3	K2SO4	KCl	Na HCO3	Na2SO4	NaCl	Total solids
2. Haripur Hazara															
0—1	..	..	0·0376	0·0029	0·0092	..	..	0·0128	..	..	0·0023	..	..	0·0063	0·088
1—2	..	..	0·0318	0·0044	0·0079	..	..	0·0128	..	..	..	..	..	0·0111	0·078
2—3	..	..	0·0347	0·0044	0·0059	..	..	0·0107	..	..	0·0008	..	..	0·0108	0·085
3—4	..	..	0·0405	0·0058	0·0007	..	..	0·0128	..	..	..	..	..	0·0230	0·105
4—5	..	..	0·0405	..	..	..	0·0039	0·0034	..	..	0·0008	..	..	0·0172	0·075
34. Tabiji															
0—1	..	..	0·0289	0·0058	0·0017	..	..	0·0086	..	..	0·0031	..	..	0·0160	0·068
1—2	..	..	0·0231	0·0160	0·0126	..	..	0·0150	..	..	0·0031	..	..	0·0464	0·128
2—3	..	..	0·0162	..	..	0·0099	..	..	0·0010	..	..	0·0040	0·0198	0·0658	0·105
3—4	..	..	0·0040	..	..	0·0066	..	..	0·0010	..	..	0·0414	0·0198	0·0600	0·113
4—5	..	..	0·0061	..	..	0·0066	..	..	0·0010	..	..	0·0213	0·0076	0·0249	0·050
52. Koilpatti															
0—1	..	..	0·0101	..	..	0·0066	..	..	..	..	..	0·0660	0·0091	0·0234	0·093
1—2	..	..	0·0121	..	..	0·0066	..	..	0·0031	..	..	0·0733	0·0244	0·0746	0·165
2—3	..	..	0·0608	0·3055	..	..	0·1758	..	..	0·0036	..	..	0·3857	0·2516	1·280
3—4	..	..	0·0434	0·6963	..	..	0·3110	..	..	0·0054	..	..	0·5235	0·3452	2·190
4—5	..	..	0·0372	0·6139	..	..	0·3191	..	..	0·0063	..	..	0·4601	0·3335	1·903
36. Karimganj															
0—1	..	..	0·0116	0·0029	0·0035	..	..	0·0086	..	..	0·0015	..	..	0·0153	0·065
1—2	..	..	0·0087	0·0015	0·0039	..	..	0·0128	..	..	0·0023	..	..	0·0178	0·070
2—3	..	..	0·0087	0·0073	0·0033	..	..	0·0150	..	..	0·0023	..	..	0·0333	0·095
3—4	..	..	0·0087	0·0015	0·0067	..	..	0·0128	..	..	..	..	..	0·0269	0·075
4—5	..	..	0·0087	0·0015	0·0067	..	..	0·0128	..	..	0·0015	..	..	0·0257	0·075
54. Hagari					MgCO3						Na2CO3				
0—1	..	0·0025	..	..	0·0019	..	..	..	..	..	0·0025	0·1020	0·0137	0·0380	0·135
1—2	0·0008	0·0020	..	..	..	..	..	..	..	..	0·0054	0·0840	0·0974	0·1551	0·333
2—3	0·0010	0·0036	0·0463	0·0064	..	..	0·0189	..	..	0·0018	..	..	0·5313	0·2312	0·845
3—4	..	..	0·0579	0·0125	..	..	0·0216	..	..	..	..	..	0·5399	0·2136	0·855
4—5	..	..	0·0121	..	..	0·0082	..	..	..	..	..	0·0677	0·2223	0·2077	0·505
56. Samalkot											K2CO3				
0—1	..	0·0025	..	..	..	..	..	..	0·0092	..	0·0015	0·0463	0·0137	0·0293	0·110
1—2	..	0.0036	0·0023	..	..	0·0033	..	..	0·0144	..	..	0·0417	0·0091	0·0497	0·175
2—3	..	0·0025	..	..	0·0019	..	..	..	0·0138	..	0·0033	0·0245	0·0091	0·0439	0·155
13. Mirpurkhas															
0—1	0·0026	..	0·0292	0·0085	0·0073	..	..	0·0117	..	..	0·0207	..	..	..	0·095
1—2	0·0013	..	0·0319	0·0014	0·0038	..	..	0·0117	..	..	0·0183	..	..	0·0041	0·070
2—3	..	..	0·0121	..	..	0·0240	..	..	0·0030	0·0036	0·0309	..	..	0·0203	0·080
3—4	..	..	0·0324	..	..	0·0128	0·0093	..	..	0·0011	0·0391	..	..	0·0222	0·098
4—5	..	..	0·0202	..	..	0·0120	..	..	0·0045	0·0651	..	..	0·0076	0·0413	0·075

25. Akola															
0—1	..	..	..	.	.	0·0066	..	..	0·0010	..	..	0·0234	0·0030	0·0059	0·053
1—2	..	.	0·0248			0·0033	..	..	0·0010	..	..	0·0644	0·0015	0·0059	0·058
2—3	.	..	..			0·0033	..	..	0·0021	..	..	0·0845	0·0030	0·0088	0·070
3—4	..	..				0·0067	..	.	0·0041	.	.	0·0940	0·0030	0·0059	0·083
4—5	..	..	.			0·0033	.		..	.	.	0·1192	0·0046	0·0117	0·095
27. Labhandi															
0—1	..		0·0142		..	0·0055	..	.	..	..	.			0·0039	0·036
1—2	.		0·0101	..	..	0·0060	.	..	.	..	..	0·0034	.	0·0044	0·035
2—3	..		0·0061	.		0·0053	.	..	.	..	.	0·0115	..	0·0029	0·032
3—4	.		0·0122		..	0·0083			0·0016			0·0303	..	0·0073	0·054
4—5	.	.	0·0134	.	..	0·0130	..	.	0·0057	..		0·0260	..	0·0044	0·060
26. Warasoeni															
0—1	..	..	0·0324	..	..	0·0033	..	..	0·0020	..	0·0085	..	..	0·0124	0·068
1—2	..	..	0·0081	..	..	..	..	..	0·0010	..	..	0·0058	0·0030	0·0073	0·023
2—3	..	..	0·0162	..	..	..	..	..	0·0082	..	..	0·0003	0·0046	0·0102	0·033
3—4	..	..	0·0121	..	..	..	..	..	0·0031	..	..	0·0058	0·0061	0·0102	0·025
4—5	..	..	0·0364	..	..	..	..	..	0·0015	0·0032	..	..	0·0050	0·0102	0·073
50. Coimbatore															
0—1	..	..	0·0142	..	..	0·0003	0·0039	0·0010			0·0015	.		0·0034	0·035
1—2	..	..	0·0142	..	..	0·0055	0·0009	..		0·0006	0·0010			0·0050	0·033
2—3½	..	..	0·0445	..	..	0·0016	0·0039	0·0644			0·0008	.		0·0086	0·055
3½—4½	..	..	0·0404	..	..	0·0027	0·0039	0·0016	.		0·0008	..	.	0·0106	0·050
55. Nandyal			$MgCO_3$					K_2CO_3			Na_2CO_3				
0—1	0·0024	..	..		..	..	..		..	.	0·0076	0·1110	0·0152	0·0088	0·155
1—2	0·0008	0·0008	.	0·0019	.	.	.	..		..	0·0006	0·1140	0·0168	0·0117	0·144
2—3		0·0012		0·0019	..	..		0·0007			0·0033	0·1200	0·0244	0·0629	0·203
3—4		0·0036	0·0023	..	..	0·0033	.	.	0·2021	..	..	0·1091	0·0533	0·0585	0·225
4—5	..	0·0025	..	0·0019	..	.		..		.	0·0101	0·1200	0·1188	0·0585	0·290
57. Anakapalli				$CaSO_4$			$MgCl_2$			KCl					
0—1	..	..	0·0116	0·0005	..	..	0·0047	0·0025	.	..	0·0008	..	..	0·0139	0·040
1—2	..	..	0·0145	0·0014	..	..	0·0026	0·0044	..	..	0·0015	..	..	0·0110	0·040
2—3	..	..	0·0116	0·0005	..	..	0·0085	0·0037	..	..	..	..	..	0·0101	0·040
3—4	..	..	0·0116	0·0005	..	..	0·0022	0·0026	..	.	0·0008	.	..	0·0123	0·040
4—5	..	..	0·0116	0·0058	0·0039	..	..	0·0021		..	..	..	..	0·0210	0·073
58. Berhampur															
0—1	..	..	0·0101	..	..	0·0039	0·0022	..	..	0·0025	0·0040	..	..	0·0100	0·035
1—2	.		0·0040	.	.		.	..	0·0129	0·0022	..	..	0·0027	0·0146	0·035
2—3	..	..	0·0061	..	..	..	..	..	0·0165	..	..	0·0009	0·0061	0·0132	0·043
3—4	..	..	0·0040	..	..	0·0033	..	..	0·0084	0·0053	..	..	0·0003	0·0132	0·015
4—5	.	..	0·0020	..	.		..		0·0190	0·0015		.	0·0064	0·0161	[illegible]
11. Sakrand															
0—1	..	..	0·0376	0·0073	..	..	0·0151	..	..	0·0118	..	..	0·0114	0·0154	0·129
1—2	0·0024	..	0·0376	0·0024	..	..	0·0178	..	..	0·0161	0·0064	..	..	0·0070	0·084
2—3	0·0251		0·0319	0·0817	.		0·0232	0·0021	..		0·0289	..	..	0·0240	0·189
3—4	0·0527	.	0·0261	0·0115	..	..	0·0918	..	..	0·1116	0·0354	.	..	0·2092	0·826
4—5	0·0210	.	0·0319	0·2733	..		0·1577	.	.	0·1814	..	.	..	0·1182	1·050
48. Padegaon															
0—1	0·0009	..	0·0052	..	..	0·0033	..	..	..	..	..	0·0508	0·0289	0·0117	0·097
1—2	..	..	0·0040	..	..	0·0033	..	..	0·0021	.	..	0·0743	0·0152	0·0205	0·095
2—3	..	..	0·0061	..	..	0·0033	..	..	0·0052		..	0·0756	0·0152	0·0293	0·115
3—4	..	..	0·0463	0·0155	..	..	0·0243	..		0·0072	..	..	0·2416	0·0454	0·333
4—5	..	..	0·0318	0·6642	...	..	0·1783	..	..	0·0162	..	..	0·4227	0·0585	1·508

APPENDIX—*contd.*

The water-soluble salt contents of soil profiles

Depth in ft.	Ca $(NO_3)_2$	$CaCO_3$	Ca $(HCO_3)_2$	$CaSO_4$	$CaCl_2$	Mg $(HCO_3)_2$	$MgSO_4$	$MgCl_2$	$KHCO_3$	K_2SO_4	KCl	Na HCO_3	Na_2SO_4	NaCl	Totals solid
18. *Shahjahanpur*															
0–1	..	..	0·0203	..	..	0·0026	0·0018	0·0012	..	..	0·0018	..	..	0·0021	0·025
1–2	..	..	0·0142	..	..	0·0045	..	..	0·0012	..	0·0014	..	..	..	0·020
2–3	..	..	0·0116	0·0070	..	..	..	0·0057	..	..	..	..	..	..	0·029
3–4	..	..	0·0081	..	..	0·0031	0·0054	..	..	..	..	..	..	0·0042	0·033
4–5	..	..	0·0081	..	..	0·0005	0·0036	0·0012	..	..	..	..	..	0·0044	0·015
30. *Powerkhera*															
0–1	..	..	0·0324	..	..	0·0047	..	0·0017	..	..	0·0023	..	..	0·0034	0·044
1–2	..	..	0·0324	..	..	0·0047	..	0·0022	..	..	0·0029	..	..	0·0009	0·039
2–3	..	..	0·0243	..	..	0·0068	..	0·0004	..	..	0·0031	..	..	0·0030	0·040
3–4	..	..	0·0263	..	..	0·0090	..	..	0·0018	..	0·0013	..	..	0·0033	0·043
4–5	..	..	0·0385	..	..	0·0018	0·0020	0·0024	..	..	0·0028	..	..	0·0021	0·043
31. *Indore*															
0–1	..	..	0·0303	..	..	0·0099	..	..	0·0010	..	..	0·0044	0·0061	0·0088	0·055
1–2	..	..	0·0303	..	..	0·0040	0·0026	0·0018	..	..	0·0008	..	..	0·0038	0·040
2–3	..	..	0·0376	0·0041	..	..	0·0041	0·0031	..	..	0·0015	..	..	0·0066	0·050
3–4	..	..	0·0324	..	..	0·0074	0·0064	0·0008	..	..	..	..	..	0·0122	0·055
4–5	..	..	0·0202	..	..	0·0099	..	..	..	..	..	0·0067	0·0046	0·0073	0·043
43. *Sirsi*															
0–1	..	..	..	..	..	0·0060	..	..	0·0033	..	0·0014	..	..	0·0039	0·028
1–2	..	..	..	..	..	0·0060	..	..	0·0033	..	0·0014	..	..	0·0055	0·020
2–3	..	..	0·0040	..	..	0·0047	..	0·0008	..	..	0·0019	..	..	0·0041	0·023
3–4	0·0018	..	0·0027	..	..	0·0060	..	..	..	..	0·0019	..	..	0·0051	0·027
4–5	0·0018	..	..	..	..	0·0048	..	0·0008	..	..	0·0019	..	..	0·0041	0·023
49. *Surat*															
0–1	..	..	0·0202	..	..	0·0081	..	0·0025	..	..	0·0024	..	..	..	0·043
1–2	..	..	0·0202	..	..	0·0129	..	..	..	..	..	..	..	0·0066	0·042
2–3	..	..	0·0243	..	..	0·0069	..	0·0033	..	..	0·0019	..	..	0·0010	0·044
3–4	..	..	0·0243	..	..	0·0093	..	0·0018	..	..	0·0019	..	..	0·0062	0·045
4–5	..	..	0·0243	..	..	0·0093	..	0·0018	..	..	0·0019	..	..	0·0095	0·045
28. *Chandkhuri*															
0–5 in.	..	..	0·0081	..	..	0·0066	..	..	0·0031	..	..	0·0085	0·0015	0·0073	0·020
5–16 in.	..	..	0·0142	..	..	0·0033	..	..	0·0021	..	..	0·0098	0·0015	0·0073	0·025
16–28 in.	..	..	0·0182	..	..	0·0066	..	..	0·0031	..	..	0·0010	0·0015	0·0102	0·025
28–40 in.	..	..	0·0081	..	..	0·0033	..	..	..	..	..	0·0058	0·0030	0·0073	0·028
40–52 in.	..	..	0·0081	..	..	0·0031	0·0026	0·0002	..	..	..	..	..	0·0071	0·025
52–60 in.	..	..	0·0081	..	..	0·0031	0·0001	..	..	..	..	..	0·0014	0·0078	0·028
29. *Kheri Adhartal*															
0–1	..	..	0·0405	0·0044	0·0049	..	..	0·0107	..	..	..	..	..	..	0·043
1–2	..	..	0·0404	..	..	0·0053	0·0039	0·0042	..	..	0·0015	..	..	0·0053	0·040
2–3	..	..	0·0405	0·0016	..	..	0·0011	0·0077	..	..	..	..	..	..	0·038
3–4	..	..	0·0384	..	..	0·0045	0·0026	0·0036	..	..	..	..	..	..	0·043
4–5	..	..	0·0344	..	..	0·0029	0·0039	0·0057	..	..	0·0008	..	..	..	0·040

32. *Kharua*															
0—1	..	..	0·0546	..	..	0·0030	0·0064	0·0037	..	..	..	..	..	0·0218	0·063
1—2	..	..	0·0434	0·0009	..	..	0·0031	0·0040	..	..	..	..	..	0·0126	0·048
2—3	..	..	0·0364	..	..	0·0063	0·0039	0·0014	..	..	..	..	..	0·0203	0·043
3—4	..	..	0·0384	..	..	0·0011	0·0052	0·0011	..	..	..	..	..	0·0103	0·045
4—5	..	..	0·0283	..	..	0·0066	..	..	..	..	..	0·0021	0·0046	0·0012	0·045
38. *Dacca*															
0—1	..	..	0·0101	..	..	0·0013	0·0026	0·0014	..	..	..	..	..	0·0036	0·035
1—2	..	..	0·0040	..	..	0·0033	..	..	..	..	..	0·0100	0·0015	0·0073	0·023
2—3	..	..	0·0040	..	..	0·0033	..	..	..	..	..	0·0100	0·0015	0·0073	0·018
3—4	..	..	0·0040	..	..	0·0066	..	..	..	..	..	0·0033	0·0015	0·0073	0·020
4—5	..	..	0·0040	..	..	0·0033	..	..	0·0012	0·0007	..	..	0·0025	0·0044	0·018
59. *Pusa*															
0—8 in.	0·0020	..	0·0404	..	..	0·0018	0·0066	..	..	..	..	..	0·0059	0·0039	0·048
1—2	0·0012	..	0·0311	..	..	0·0033	0·0039	0·0012	..	..	0·0015	..	..	0·0046	0·055
2—3	0·0079	..	0·0318	0·0044	0·0025	..	..	0·0064	..	..	..	..	..	0·0041	0·068
3—4	0·0063	..	0·0289	0·0044	0·0042	..	..	0·0107	..	..	..	..	..	..	0·070
4—5	0·0045	..	0·0260	0·0033	..	..	0·0023	0·0068	..	..	..	..	..	0·0048	0·055
60. *Delhi*															
0—1	..	..	0·0324	..	..	0·0066	..	..	0·0010	..	..	..	0·0061	0·0088	0·043
1—2	..	..	0·0283	..	..	0·0006	0·0022	..	..	..	..	..	0·0004	0·0073	0·040
2—3	..	..	0.0269	..	..	0·0018	0·0015	..	..	..	..	..	0·0012	0·0073	0·038
3—4	..	..	0·0283	..	..	0·0033	..	..	..	..	..	0·0029	0·0030	0·0073	0·043
4—4ft. 10 in.	..	..	0·0222	..	..	0·0099	..	..	..	..	..	0·0016	0·0030	0·0044	0·040

COMPARATIVE STUDIES ON INDIAN SOILS.

VII. CARBON AND NITROGEN STATUS OF INDIAN SOILS AND THEIR PROFILES

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(Received for publication on 21 March 1944)

(With one text-figure)

In Part I of this series, Viswanath and Ukil [1944] dealt with the regional and environmental factors associated with Indian soils. The carbon and nitrogen status of a soil and the ratio of carbon by nitrogen are important considerations both from the points of view of the developmental process in the soil and its agricultural value. A great deal of information on the carbon and nitrogen ratio of cold and temperate regions of the world is available but very little information is available on Indian soils. It is well known that cultivation brings about changes in the carbon and nitrogen levels of a soil. To obtain a precise information on the carbon and nitrogen contents of uncultivated and undisturbed soils, 43 profiles samples collected from all over India in the months of February and March, 1937, have been examined. The data for the carbon and nitrogen contents of the profiles have been obtained and these and the calculated carbon-nitrogen ratios are given in the appendix.

Experimental

Total nitrogen was estimated by the wet digestion method of Bal [1925] and by the dry digestion method described in *A. O. A. C.* [1935]. Organic carbon was estimated by the dry combustion method of *A. O. A. C.* [1935]. The organic carbon content has been obtained after making allowance for carbon-dioxide of carbonates estimated in the original sample and in the residual soil after dry combusion. Precaution was taken to ascertain that the soil samples taken for carbon estimation did not contain pieces of wood, charcoal bits, etc.

Results

For purposes of determining the carbon and nitrogen status of the soils in relation to climate and colour classification, it will facilitate discussion if the soils are listed as shown in Table I.

Table I

Grouping of the soils on climatic and colour basis

(The numbers correspond to those given in the appendix)

Climatic division / Colour division	Arid	Semi-arid	Humid	Per-humid
Black	—	45. Akola 31. Indore 32. Kharua 48. Padegaon 92. Surat 52. Koilpatti 54. Hagari 55. Nandyal	24. Nagpur 27. Labhandi 29. Kheri-Adhartal 30. Powerkhera 26. Samalkot	—
Brown	2. Haripur Hazara 9. Lyallpur	34. Tablji 50. Coimbatore 57. Anakapalle 60. Delhi	40. Chinsura 18. Shahjahanpur	8. Kangra 35. Jorhat 36. Karimganj 73. Sylhet
Red	—	—	26. Waraseoni 22. Ranchi 28. Chandkheri	38. Dacca 35. Sirsi 51. Taliparamba
Grey and pink	10. Mianwali	3. Lahore 7. Gurdaspur 33. Makrera	58. Berhampur	39. Rangpur
Calcareous	1. Peshawar 11. Sakrand 12. Karachi	—	19. Padrauna 59. Pusa	

In the brown soils of the arid region the carbon content decreases more rapidly with depth than the nitrogen content and the C/N ratio narrows down with depth. The nitrogen content of the brown soils from Tabiji, Coimbatore and Anakapalle of the semi-arid zone does not differ much with depth and so is the case with carbon. The carbon-nitrogen ratio on the average is above 11 with slight variations in the profile.

In Chinsura and Shahjahanpur soils of the humid region the carbon content is either steady or increases slightly within the first three feet and then decreases in the fourth and fifth foot. The carbon contents in the first foot of Chinsura and Shahjahanpur are 0·69 and 0·22 per cent respectively. The nitrogen content of Chinsura soil varies from 0·086 per cent in the first foot depth to 0·051 at the fifth foot. At Shahjahanpur the soil nitrogen is practically the same 0·032 at the first and fifth foot. The C/N ratio of the brown soils in the humid zone increases in the second and third foot and narrows down later. Four profiles of brown soil from Kangra, Jorhat, Karimganj and Sylhet of the per-humid region show a gradual decrease of carbon and nitrogen with depth. The surface soils contain high amounts of carbon and nitrogen with an average C/N ratio of 12·2, narrowing with depth. There are definite signs of leaching and accumulation of carbon in the second foot depth of Sylhet soil.

In grey and pink soils of the arid zone the carbon and nitrogen contents decrease with depth and C/N ratio on an average is high with values in the first foot of 11·4 in Mianwali and 16·7 in Mirpurkhas. The average C/N ratio for the profile is above 10. The grey and pink soils of Lahore, Gurdaspur and Makrera in the semi-arid region contain a fairly high proportion of nitrogen and the level is almost maintained in all depths. The carbon content is low and the C/N ratio is very narrow (5·0) with slight decrease in the profile. Makrera soils contain over 15 per cent lime as calcium carbonate and the average C/N ratio in the first three feet is 12·9 and 7·6 in the 3-5 ft. depth. In Berhampur soil of the humid region the nitrogen content remained steady in the profile but the carbon content decreases with depth and the C/N ratio narrows from 11·21 at the surface to 6·0 at the last depth. In Rangpur profile of per-humid zone both carbon and nitrogen decrease with depth and the C/N ratio narrows down from 13·8 at the surface to 1·9 at the last depth.

The black soils examined are located in the semi-arid and humid regions. The nitrogen content of the surface soils in the semi-arid region varies from 0·022 per cent in Koilpatti to 0·076 in the black soil of Surat. The nitrogen content at the lower depths, though lower than in the surface soils, remains fairly uniform. Similarly the carbon content of surface soil varies from 0·30 per cent at Hagari to 1·26 per cent at Kharua. The C/N ratio in all the profiles does not vary much with depth and the ratios are generally wide. The average C/N ratios of the profiles from Kharua, Padegaon, Koilpatti, Hagari and Nandyal are 20·7, 19·5, 21·8, 15·3 and 20·8 respectively. The black soils of the humid region are from Nagpur, Labhandi, Kheri, Powerkhera and Samalkot, the last mentioned being an alluvial black soil. The carbon and nitrogen contents in the surface soils are similar to those in the semi-arid region, and decrease slightly with depth. The C/N ratios of the surface soils vary between 10·7 and 14·0. Considering the averages for the profile, only Nagpur and Kheri soils show the wide ratios of 16·3 and 17·1 respectively. There is a clear indication that as the amount of rainfall increases the C/N ratio narrows down in the black soils. This is borne out when the average C/N ratio of the black soils of the semi-arid and humid region are compared, the ratio decreasing from 14·6 in the semi-arid to 12·9 in the humid zone.

The red soil profiles are from the humid and per-humid regions. In the profiles from Ranchi and Chandkhuri of the humid region there are indications of leaching down of organic matter and accumulation in the lower horizons. The surface soil and the layers below contain 0·036 per cent nitrogen at Ranchi, while it is 0·062 in the surface soil and 0·08 in the second layer decreasing later with depth in the Chandkhuri profile. The C/N ratio of the surface soils is near about 14·0 but the ratio decreases with depth. The average C/N ratio for the profiles of Ranchi and Chandkhuri is 10 and 12·7 respectively. The profiles of Sirsi and Taliparamba are from the per-humid zone. The surface soils in both the places contain high amounts of carbon and nitrogen, which decrease with the depth of the profile. The C/N ratio of Sirsi profile narrows down from 10·4 at the surface to 5·0 in the fifth foot. In the case of Taliparamba soil the C/N ratio does not show such wide difference with depth, C/N ratio in the first foot being 11·8 and 9·8 in the fifth foot.

The calcareous soils from Peshawar, Sakrand and Karachi in the arid region and two soils from Padrauna and Pusa have also been examined. In Peshawar soil the surface soil has a nitrogen value of 0·077 per cent and from the second foot downwards remains constant with 0·03 per cent. The carbon content also decreases proportionately and the C/N ratio is fairly uniform with an average value of 11·8. In Sakrand soil also the surface value for nitrogen is 0·052 and remains steady at 0·03 in the second foot and downwards. Carbon decreases with depth with an accumulation in the third and fourth foot. The C/N ratio in the surface soil is narrow but widens in the lower depths. The Karachi soil is very poor in nitrogen, 0·018 per cent, which remains constant in the profile. The C/N ratio decreases from 17·9 in the surface to 8·8 in the last depth. In Padrauna sample the carbon content is 1·1 per cent, nitrogen 0·099 in the surface sample but both carbon and nitrogen decrease rapidly with depth and the average C/N ratio for the profile is 10·7. In Pusa soil the nitrogen content is low, 0·03 per cent, and the C/N ratio is wide with a value of 14·06 in the surface sample and an average value of 16·8 for the profile.

Confining the attention to the surface soils, the average carbon and nitrogen content and the C/N ratios in the different climatic zones and colour groups of soils are as shown in Table II. The calcareous soils are included in Table II as a distinct group.

TABLE II

The average carbon and nitrogen content and C/N ratios in different climatic zones and colour groups

(The blanks in the table denote that there are no soils of that colour in the paticular climatic zone)

Climatic division / Colour division	Arid	Semi-arid	Humid	Per-humid
Black—				
Organic (C) carbon mg. per cent	..	717	709	..
Nitrogen (N) mg. per cent	..	49	55	..
C/N	..	14·6	12·9	..
Brown—				
C	645	362	..	1,096
N	68	33	..	90
C/N	9·5	11·0	..	12·2
Red—				
C	..	..	680	1,539
N	..	..	49	137
C/N	..	..	13·9	11·2
Grey and pink—				
C	513	486	247	1,430
N	38	65	22	105
C/N	13·5	7·5	11·2	13·6
Calcareous—				
C	495	..	1,100	..
N	49	..	99	..
C/N	10·1	..	11·1	..
Average—				
C	543	592	639	1,234
N	51	49	54·6	102
C/N	10·6	12·2	11·7	12·1

DISCUSSION

The influence of climate on humus in the soil has been discussed by Lang [1920]. Smolik [1926] has shown that total organic matter shows no variation with the rain factor, but that the chemical composition of humus appeared to be related to climate. Russel and McRuer [1927] in their investigation of organic matter and nitrogen content of virgin Nebraska soils found a linear relation-

ship between nitrogen and annual rainfall after reducing the soils to a common hygroscopic coefficient to eliminate variation due to texture.

Hans Jenny [1929, 1932] has shown a relationship between mean annual temperature and total nitrogen content. According to him climate is the outstanding factor which controls the nitrogen level of the loamy soils of the United States examined by him. Vegetation is the next important factor, while topography and parent material probably rank third and fourth. The nitrogen values for soils of Russia, Norway, Denmark, Switzerland and Italy do not seem to contradict Jenny's view. But the soils of Palestine do not come under this category.

The Indian soils which have been grouped into arid, semi-arid, humid and per-humid zones on the basis of N.S.Q., on lines similar to those of Jenny, give a picture different from the soils of the United States or Europe. In India the mean annual temperatures for a majority of places from where the soils have been studied are between 75°. to 80°F. The total carbon and nitrogen contents of the American and European soils are in many cases four times the values and even more as compared to those of India. Considering the values for the nitrogen contents of soils in the several zones, it is seen that if the data are plotted against temperature the figures for the arid, semi-arid and humid zones do not give a curve approaching anywhere to those obtained by Jenny (Fig. 1). On the other hand, when the points are joined irregular curves with several peaks and troughs are obtained. Hence the points on the graph are located but not joined. It is only in the case of values for the soils in the semi-arid zone that a tendency to approximate that of Jenny can perhaps be suspected.

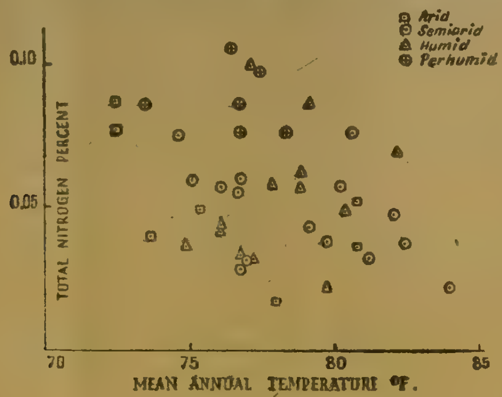

FIG. 1. Nitrogen content of surface soils in relation to temperature of different climatic zones

In regard to carbon and nitrogen ratios Russel [1937] and several others have observed that in temperate regions the ratio is usually about 10 to 12 and that there is no definite relationship between climate and carbon nitrogen ratio. Jenny has made the passing observation that C/N ratio of the soil organic matter seems to become narrower with increasing temperatures.

McLean [1930] found that the C/N ratio of 50 British soils work at 10·2 ± 0·3 and form a normal frequency curve with a well defined maximum at 9·5 to 10·4 although the range is from 6·5 to 13·5. Our data on Indian soils has shown that many soils have ratios very much narrower than 10 (of the order of 4 and 5) and very much wider even going over 25. Leighty and Shorey [1930] have suggested the use of a mean C/N ratio of the profile in comparing various soil profiles. In the case of Indian soils, considering the C/N ratio of surface soils the maximum frequency distribution occurs between 11 and 13 and for the average C/N ratio of the profile the maximum frequency distribution lies between 10 and 12. The soils in the Punjab and Sind have generally narrower ratios compared to other places.

In the present study the soils included differ widely in their mechanical composition and texture. The effect of the textural differences on the C/N ratio of the sufrace soils and the average C/N ratio of the profiles has been examined. The data are presented in Table III.

TABLE III

Carbon and nitrogen ratios for the surface soils and average values for the profile and pH in the soils of different texture

Sandy loam				Silty loam				Loam				Clay loam			
Soil No.	pH	C/N Ratio		Soil No.	pH	C/N Ratio		Soil No.	pH	C/N Ratio		Soil No.	pH	C/N Ratio	
		Surface soil	Average			Surface soil	Average			Surface soil	Average			Surface soil	Average
10.A	7·31	11·4	10·7	11.A	7·69	6·4	8·7	13.A	7·34	15·7	12·5	54.S	8·75	10·7	15·3
9.A	7·59	7·5	4·3	1.A	7·90	10·7	11·3	3.S	8·21	5·4	3·9	48.S	7·97	19·3	19·5
33.S	6·65	13·8	10·8	2.A	7·14	11·2	6·0	18.H	8·0	6·7	6·5	55.S	8·47	18·5	20·8
34.S	7·15	10·9	9·7	7.S	7·88	5·1	4·8	56.H	7·06	14·0	12·5	32.S	7·51	22·9	20·7
50.S	7·05	11·2	11·8	8.P	6·93	11·0	6·9	28.H	7·16	12·2	12·7	25.S	7·91	12·7	12·4
60.S	7·30	9·7	8·2	36.P	5·91	9·0	9·4	26.H	6·46	11·6	10·5	31.S	7·78	12·8	11·1
57.H	7·91	11·1	11·2	..	..	..	..	38.P	5·69	13·0	10·6	52.S	8·05	23·6	21·8
58.H	6·05	11·2	7·6	..	..	..	..	51.P	4·66	11·8	11·2	..	..	..	..
59.H	7·28	14·1	16·8	..		..	..	..	..	..	..	49.H	7·17	7·5	10·0
19.H	7·69	11·1	10·7	..	..	..	..	..	..	..	..	30.H	6·68	10·7	11·3
39.P	5·69	13·8	7·5	..	..	..	..	..	..	..	..	24.H	7·31	12·1	16·3
35.P	4·26	12·4	9·6	..	...	..	..	..	..	..	..	27.H	6·41	13·4	11·1
37.P	4·84	7·5	4·9	..	..	..	..	..	..	..	..	29.H 22.H	7·51 6·57	10·7 13·7	17·1 10·0
42.P	3·74	10·4	6·7	..	..	..	..	..	..	..	..	40.H	[illegible]	8·1	[illegible]
Average	..	11·2	9·3	..	..	8·9	7·9	..	..	11·3	10·1	..	..	14·1	14·7

The letters after the soil number stand for as A = Arid ; S — semi-arid ; H = Humid P = Perhumid.

The average values indicate that the C/N ratio is 10·1 ± 1·2 for the sandy loam, silty loam and loamy soils. In the case of clay loam soils the C/N ratio is wide with a general average of 14·4. It is particularly interesting to note that 12 out of the 14 soils are black soils, the other two being a red soil of Ranchi and brownish black soil of Chinsura. Seven of the black soils are from the semi-arid region and their mean C/N ratio is 17·3 while the rest of the 7 soils are from the humid region with an average C/N ratio of 12·1.

McLean [1930] observed wide C/N ratios of the order 23·0 from Sudan clay. The C/N ratios of the semi-arid black soils of India are comparable with other tropical black soils in respect of the wide C/N ratios. The fact that the C/N ratio of the humid black soils is narrower compared to the semi-arid soils is indicative that moisture supply in heavy black soils appears to be a limiting factor in carbon oxidation. Anderson and Byers [1934] observed that wide divergence exists between the C/N ratio of the soil groups chernozem, prairie, podsol, grey brown and laterite. However, they found the most consistant ratio 9·0 (maximum 10 and minimum 7·5) in the chernozem group of soils. Thus it appears that the tropical black soils are not comparable to the chernozems in respect of their C/N ratios.

It is clear from the foregoing discussion of the data presented in the paper, that the general level of carbon and nitrogen in the uncultivated soils and profiles is low. Under normal agricultural practices the soils are liable to be depleted still further of their organic matter. The high mean annual temperatures of 24°C., 26°C., 25°C. and 24·4°C. in the arid, semi-arid, humid and per-humid regions respectively do not permit the building up of organic matter reserves. Thus the Indian soils require adequate and constant supply of organic matter and nitrogen in most cases is substantiated. The significance of these unusually wide and narrower C/N ratios in respect of nitrogen transformation processes and soil fertility as determined by crop yield will be discussed in a subsequent communication.

Summary

The organic carbon and nitrogen contents of 43 uncultivated soil profiles distributed all over India have been examined. The fluctuations in the carbon and nitrogen contents in the soil colour groups brown, black, red, grey and pink and calcareous soils, under arid, semi-arid, humid and per-humid regions have been discussed. The general level of the carbon and nitrogen in most of the soils is low. No correlation between climate and nitrogen content could be traced. The carbon/nitrogen ratios fluctuate widely from 5 to 25.

Barring the black soils of the semi-arid region the maximum frequency of the average C/N ratio occurs between 10 and 12. The semi-arid black soils show unusually wide C/N ratios. In view of the high mean annual temperatures in India, the need for adequate supply of organic matter and nitrogen to the soils is evident.

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APPENDIX

Carbon, nitrogen contents in successive horizons of soil profiles in arid region

(N. S. Quotitient below 100)

Depth. in inches	*p*H	CO_2	Organic carbon	Nitrogen		$CaCo_3$	C/N
				Wet	Dry		
2. *Haripur Hazara (Brown)*							
0—12	7·14	3·82	0·971	0·087	0·074	4·68	11·2
12—24	7·16	2·22	0·417	0·105	0·084	5·06	4·4
24—36	7·04	2·10	0·521	0·100	0·088	4·77	5·5
36—48	7·03	1·15	0·374	0·100	0·080	2·63	4·2
48—60	7·15	1·63	0·365	0·100	0·084	3·70	4·9
9. *Lyallpur (Brown)*							
0—12	7·59	0·292	0·320	0·049	0·035	0·66	7·5
12—24	7·10	0·504	0·191	0·044	0·036	1·15	4·8
24—36	6·56	0·130	0·144	0·037	0·037	0·30	3·9
36—48	6·46	0·396	0·047	0·031	0·033	0·90	1·4
48—60	6·35	0·126	0·155	0·037	0·039	0·29	4·1
10. *Mianwali (Grey and pink)*							
0—12	7·31	2·80	0·457	0·040	0·040	6·36	11·4
12—24	7·51	2·11	0·239	0·024	0·024	4·80	10·0
24—36	7·67	2·85	0·281	0·024	0·024	6·48	11·7
36—48	7·91	4·64	0·223	0·027	0·022	10·55	8·3
48—60	7·94	0·24	0·369	0·030	0·030	0·55	12·3
13. *Mirpurkhas (Grey and pink)*							
0—12	7·34	4·34	0·569	0·036	0·032	9·86	15·8
12—24	7·48	4·13	0·343	0·032	0·032	0·43	10·7
24—36	7·63	3·63	0·368	0·028	0·028	8·25	13·1
36—48	7·64	2·79	0·339	0·030	0·030	6·35	11·3
48—60	7·81	2·54	0·353	0·034	0·032	5·77	10·7
1. *Peshawar (Calcareous)*							
0—12	7·90	8·02	0·856	0·077	0·083	18·20	10·7
12—24	8·37	8·58	0·403	0·030	0·035	19·50	12·4
24—36	8·35	8·27	0·336	0·033	0·028	18·80	11·1
36—48	8·94	7·87	0·327	0·034	0·031	17·93	10·1
48—60	8·57	8·58	0·347	0·031	0·026	19·50	12·3
11. *Sarkand (Calcareous)*							
0—12	7·69	5·22	0·325	0·052	0·050	11·90	6·4
12—24	7·80	4·81	0·237	0·037	0·037	10·93	7·4
24—36	7·23	3·70	0·470	0·033	0·033	8·40	14·1
36—48	7·24	4·88	0·432	0·035	0·040	11·10	11·4
48—60	7·27	5·06	0·221	0·039	0·041	11·50	5·0
12. *Karachi (Calcareous)*							
	7·14	9·88	0·305	0·017	0·017	22·45	17·9
	7·73	10·68	0·204	0·012	0·016	24·27	17·0
	7·52	11·36	0·208	0·018	0·018	25·80	11·6
	7·32	8·32	0·242	0·018	0·018	19·00	13·3
	7·40	10·12	0·115	0·018	0·018	23·00	8·8

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in semi-arid region

(N. S. Quotient 100-200)

Depth in inches	*p*H	CO_2	Organic carbon	Nitrogen		$CaCO_3$	C/N
				Wet	Dry		
25. *Akola (Black)*							
0—12	7·91	4·40	0·72	0·057	0·055	10·00	12·7
12—24	8·39	3·37	0·52	0·039	0·034	7·66	14·4
24—36	8·47	3·68	0·35	0·031	0·034	8·40	10·8
36—48	8·57	3·88	0·38	0·033	0·033	8·80	11·5
48—60	8·57	5·14	0·41	0·033	0·033	11·70	12·5
31. *Indore (Black)*							
0—12	7·78	2·07	0·65	0·057	0·044	4·70	12·8
12—24	7·81	1·10	0·55	0·050	0·039	2·50	12·3
24—36	7·53	0·41	0·43	0·046	0·037	0·93	10·3
36—48	7·41	0·57	0·20	0·041	0·030	1·30	6·5
48—60	7·67	1·13	0·33	0·036	0·026	2·57	13·8
32. *Kharau (Black)*							
0—12	7·51	1·31	1·26	0·055	0·055	2·98	22·9
12—24	7·45	2·63	0·663	0·034	0·034	6·00	19·5
24—36	7·38	2·92	0·300	0·037	0·037	6·64	21·6
36—48	7·60	2·71	0·729	0·036	0·036	6·16	20·3
48—60	7·63	2·50	0·693	0·036	0·036	5·68	19·3
48. *Padegaon (Black)*							
0—12	7·97	4·32	0·83	0·043	0·037	9·80	19·3
12—24	8·19	3·07	0·86	0·042	0·034	7·00	20·5
24—36	8·03	3·61	0·86	0·040	0·033	8·20	21·5
36—48	7·98	3·39	0·68	0·036	0·026	7·70	19·0
48—60	7·55	4·30	0·54	0·031	0·022	9·80	17·4
49. *Surat (Black)*							
0—12	7·17	0·55	0·57	0·076	0·057	1·25	7·5
12—24	7·21	0·18	0·58	0·058	0·044	0·41	10·0
24—36	7·22	0·25	0·51	0·055	0·041	0·57	9·3
36—48	7·14	0·27	0·49	0·048	0·040	0·62	10·3
48—60	7·09	0·25	0·37	0·029	0·028	0·57	12·8
52. *Koilpatti (Black)*							
0—12	8·05	1·09	0·52	0·022	0·022	2·48	23·6
12—24	8·11	0·84	0·46	0·022	0·018	1·92	23·1
24—36	7·30	1·642	0·38	0·022	0·020	3·73	18·0
36—48	7·14	1·818	0·39	0·016	0·016	4·13	23·0
48—60	7·15	1·705	0·320	0·014	0·014	3·87	21·3
54. *Hagari (Black)*							
0—12	8·75	3·124	0·503	0·047	0·031	7·10	10·7
12—24	8·60	4·092	0·544	0·044	0·031	9·3	14·7
24—36	8·01	3·413	0·553	0·039	0·030	7·76	15·4
36—48	7·95	2·372	0·358	0·022	0·022	5·43	16·5
48—60	8·49	2·304	0·338	0·018	0·022	7·70	17·9

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in semi-arid region

(N. S. Quotient 100-200)

Depth in inches	pH	CO_2	Organic carbon	Nitrogen Wet	Nitrogen Dry	$CaCo_3$	C/N
			55. *Nandyal* (*Black*)				
0—12	8·47	1·734	0·685	0·036	0·038	3·94	18·5
12—24	8·58	1·232	0·560	0·026	0·026	2·80	21·5
24—36	8·71	1·492	0·429	0·026	0·022	3·40	17·9
36—48	9·16	1·965	0·488	0·024	0·024	4·47	20·3
48—60	9·15	2·104	0·572	0·024	0·022	4·78	26·0
			34. *Tabijii* (*Brown*)				
0—12	7·15	0·451	0·307	0·018	0·028	1·03	10·9
12—24	6·85	0·975	0·182	0·024	0·018	2·22	8·7
24—36	7·57	0·722	0·225	0·022	0·018	1·64	11·3
36—48	7·86	0·920	0·232	0·022	0·022	2·90	11·1
48—60	8·43	0·495	0·120	0·020	0·016	1·13	6·6
			50. *Coimbatore* (*Brown*)				
0—12	7·05	0·466	0·425	0·038	0·038	1·05	11·2
12—24	6·80	0·428	0·430	0·040	0·040	0·97	10·8
24—42	7·18	8·39	0·540	0·042	0·042	19·00	12·7
42—60	7·03	8·53	0·430	0·034	0·034	19·40	12·5
			57. *Anakpalli* (*Brown*)				
0—12	7·91	0·038	0·354	0·032	0·032	0·086	11·1
12—24	7·63	0·099	0·309	0·028	0·028	0·028	11·0
24—36	7·89	0·080	0·390	0·032	0·032	0·018	12·2
36—48	8·17	0·036	0·301	0·028	0·028	0·080	10·8
48—60	7·93	0·067	0·245	0·022	0·022	0·150	11·1
			60. *Delhi* (*Brown*)				
0—12	7·20	0·45	0·28	0·031	0·026	1·03	9·7
12—24	7·01	..	0·24	0·033	0·031	0·27	8·6
24—36	6·98	..	0·24	0·034	0·031	0·13	7·4
36—48	7·16	..	0·24	0·031	0·027	0·42	8·2
48—60	7·41	..	0·22	0·026	0·027	0·71	8·0
			3. *Lahore* (*Grey and pink*)				
0—12	8·21	0·844	0·311	0·059	0·055	1·92	5·4
12—24	7·66	0·633	0·269	0·052	0·050	1·44	5·3
24—36	7·52	0·494	0·150	0·053	0·055	1·12	2·7
36—48	8·07	0·847	0·170	0·053	0·048	1·92	3·0
48—60	8·12	2·072	0·129	0·039	0·039	4·71	3·3
			7. *Gurdaspur* (*Grey and pink*)				
0—12	7·88	0·543	0·372	0·074	0·072	1·23	5·1
12—24	7·38	0·167	0·305	0·056	0·055	0·38	5·5
24—36	7·11	0·076	0·294	0·059	0·055	0·17	5·1
36—48	7·05	0·152	0·253	0·057	0·057	0·35	4·4
48—60	7·13	0·057	0·227	0·055	0·055	0·13	4·1

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in arid region

(N. S. Quotient 100-200)

Depth. in inches	pH	CO_2	Organic carbon	Nitrogen Wet	Nitrogen Dry	$CaCO_3$	C/N
33. *Makrera (Grey and pink)*							
0—12 . . .	6·65	0·78	0·82	0·060	0·058	1·88	13·8
12—24 . . .	6·75	0·09	0·45	0·036	0·037	0·21	12·6
24—36 . . .	6·80	0·07	0·44	0·034	0·034	0·16	12·4
36—48 . . .	6·98	7·78	0·23	0·028	0·027	17·70	8·5
48—60 . . .	7·00	6·45	0·13	0·021	0·019	14·66	6·7
24. *Nagpur (Black)*							
0—12 . . .	7·31	1·20	0·595	0·049	0·046	2·73	12·1
12—24 . . .	7·51	0·32	0·596	0·040	0·040	0·74	14·9
24—36 . . .	7·38	0·33	0·681	0·034	0·033	0·74	19·9
36—48 . . .	7·54	0·27	0·582	0·033	0·033	0·61	18·0
48—60 . . .	8·04	2·40	0·483	0·030	0·030	5·45	16·5
27. *Labhandi (Black)*							
0—12 . . .	6·41	0·058	0·90	0·057	0·060	0·13	13·4
12—24 . . .	6·47	0·011	0·60	0·059	0·044	0·03	11·7
24—36 . . .	6·68	0·013	0·44	0·057	0·046	0·03	8·5
36—48 . . .	7·68	0·034	0·54	0·049	0·041	0·08	11·8
48—60 . . .	7·75	0·055	0·43	0·460	0·031	0·12	10·3
29. *Kheri-Adhartal (Black)*							
0—12 . . .	7·51	0·19	0·458	0·043	0·032	0·45	14·3
12—24 . . .	7·40	0·147	0·486	0·033	0·024	0·33	20·2
24—36 . . .	7·40	1·316	0·373	0·029	0·016	2·99	23·3
36—48 . . .	7·45	1·566	0·202	0·016	0·016	3·56	12·6
48—60 . . .	7·31	1·06	0·243	0·016	0·016	2·41	15·2
30. *Powerkhera (Black)*							
0—12 . . .	6·68	0·22	0·62	0·058	0·050	0·50	10·7
12—24 . . .	6·99	0·34	0·54	0·049	0·039	0·77	11·2
24—36 . . .	7·17	0·19	0·54	0·047	0·038	0·43	11·4
36—48 . . .	7·23	0·25	0·55	0·045	0·038	0·57	12·0
48—60 . . .	7·46	0·37	0·43	0·039	0·035	0·84	11·2
56. *Samalkot (Black)*							
0—12 . . .	7·06	0·218	0·965	0·069	0·069	0·495	14·3
12—24 . . .	8·52	0·256	0·823	0·070	0·070	0·584	11·7
24—36 . . .	8·78	0·223	0·682	0·059	0·059	0·507	11·6
40. *Chinsura (Brownish black)*							
0—12 . . .	6·39	..	0·69	0·086	0·067	..	8·1
12—24 . . .	7·31	..	0·63	0·061	0·045	..	10·3
24—36 . . .	7·70	..	0·66	0·052	0·038	..	12·5
36—48 . . .	7·79	..	0·41	0·051	0·038	..	8·1
48—60 . . .	7·74	..	0·26	0·051	0·035	..	5·0

APPENDIX—*contd.*

Carbon, nitrogen contents in successive horizons of soil profiles in arid nitrogen

(N. S. Quotient 100-200)

Depth in inches	pH	CO_2	Organic carbon	Nitrogen		$CaCO_3$	C/N
				Wet	Dry		
18. *Shahjahanpur* (*Brown*)							
0—12 . . .	8·00	..	0·22	0·032	0·032	..	6·7
12—24 . . .	7·68	..	0·34	0·042	0·032	..	8·0
24—36 . . .	7·33	..	0·31	0·038	0·036	..	8·1
36—48 . . .	7·27	..	0·20	0·040	0·041	..	4·9
48—60 . . .	7·21	..	0·17	0·033	0·039	..	5·0
26. *Waraseoni* (*Greyish yellow*)							
0—12 . . .	6·46	0·103	0·487	0·042	0·038	0·234	12·2
12—24 . . .	6·95	0·032	0·402	0·037	0·033	0·073	11·5
24—36 . . .	7·95	0·109	0·357	0·033	0·022	0·248	13·2
36—48 . . .	7·56	0·172	0·179	0·033	0·022	0·390	6·6
48—60 . . .	7·09	0·105	0·205	0·031	0·018	0·240	8·8
22. *Ranchi* (*Red*)							
0—12 . . .	6·57	..	0·52	0·036	0·039	..	13·7
12—24 . . .	6·50	..	0·30	0·035	0·033	..	8·7
24—36 . . .	6·81	..	0·21	0·034	0·037	..	5·9
36—48 . . .	7·14	0·044	0·30	0·035	0·034	0·10	8·7
48—60 . . .	7·43	0·069	0·40	0·029	0·033	0·16	13·1
28. *Chandkuhuri* (*Red*)							
0—5 . . .	7·16	0·17	0·86	0·062	0·062	0·40	14·0
5—16 . . .	6·54	0·07	1·05	0·082	0·080	0·16	12·9
16—28 . . .	6·68	0·13	0·76	0·066	0·060	0·30	11·5
28—40 . . .	7·30	0·09	0·38	0·042	0·040	0·20	9·3
40—52 . . .	6·87	0·07	0·29	0·035	0·032	0·16	8·6
52—60 . . .	6·84	0·10	0·21	0·028	0·028	0·23	7·4
58. *Berhampur* (*Grey and pink*)							
0—12 . . .	6·05	0·025	0·247	0·022	0·022	0·06	11·2
12—24 . . .	6·12	..	0·167	0·022	0·022	..	7·6
24—36 . . .	6·93	0·042	0·133	0·022	0·022	0·10	6·0
36—48 . . .	7·08	0·032	0·142	0·020	0·022	0·07	7·0
48—60 . . .	7·13	0·073	0·118	0·020	0·020	0·17	6·0
19. *Padrauna* (*Calcareous*)							
0—12 . . .	7·69	16·45	1·10	0·099	0·097	37·40	11·1
12—24 . . .	7·88	21·56	0·23	0·027	0·025	49·00	8·9
24—36 . . .	7·93	22·77	0·19	0·015	0·015	51·75	11·9
36—48 . . .	7·96	23·10	0·15	0·015	0·013	52·50	10·4
48—60 . . .	7·83	24·53	0·17	0·013	0·015	55·75	11·4
59. *Pusa* (*Calcareous*)							
0—12 . . .	7·28	15·84	0·46	0·033	0·030	35·99	14·1
12—24 . . .	7·44	17·45	0·49	0·033	0·035	39·66	14·2
24—36 . . .	7·21	17·88	0·35	0·020	0·020	40·53	17·5
36—48 . . .	7·28	19·65	0·36	0·020	0·020	44·67	18·8
48—60 . . .	7·45	21·06	0·37	0·018	0·018	47·86	19·5

APPENDIX—*concld.*

Carbon. nitrogen contents in successive horizons of soil profiles in per-humid region

(N. S. Quotient 400 and above)

Depth. in inches	pH	CO_2	Organic carbon	Nitrogen Wet	Nitrogen Dry	$CaCO_3$	C/N
			8. *Kangra (Brown)*				
0—12 . . .	6·93	..	1·196	0·112	0·105	..	11·1
12—24 . . .	6·77	..	0·746	0·075	0·074	..	10·0
24—36 . . .	6·77	..	0·327	0·050	0·046	..	6·8
36—48 . . .	6·81	..	0·206	0·047	0·036	..	5·0
48—60 . . .	6·38	..	0·059	0·031	0·32	..	1·8
			35. *Jorhat (Brown)*				
0—12 . . .	4·26	..	1·04	0·086	0·683	..	12·4
12—24 . . .	4·10	..	0·51	0·042	0·039	..	12·6
24—36 . . .	4·05	..	0·16	0·030	0·031	..	5·2
36—48 . . .	4·03	..	0·25	0·024	0·024	..	10·0
48—60 . . .	4·10	..	0·17	0·020	0·021	..	8·0
			36. *Karimganj (Brown)*				
0—12 . . .	5·81	..	0·777	0·086	0·086	..	9·3
12—24 . . .	5·88	..	0·561	0·070	0·070	..	8·0
24—36 . . .	5·80	..	0·580	0·048	0·048	..	12·3
36—48 . . .	5·91	..	0·523	0·048	0·048	..	10·9
48—60 . . .	6·22	..	0·325	0·048	0·048	..	6·8
			37. *Sylhet (Brown)*				
0—12 . . .	4·84	..	0·57	0·076	0·076	..	7·5
12—24 . . .	4·45	..	0·76	0·074	0·074	..	10·3
24—36 . . .	4·17	..	0·15	0·068	0·068	..	2·3
36—48 . . .	3·94	..	0·15	0·071	0·071	..	2·2
48—60 . . .	4·14	..	0·13	0·061	0·061	..	2·2
			38. *Dacca (Greyish brown)*				
0—12 . . .	5·69	..	0·982	0·076	0·076	..	13·0
12—24 . . .	4·64	..	0·497	0·056	0·052	..	9·2
24—36 . . .	4·74	..	0·436	0·044	0·042	..	10·1
36—48 . . .	4·94	..	0·389	0·032	0·032	..	12·1
48—60 . . .	5·24	..	0·243	0·030	0·028	..	8·4
			43. *Sirsi (Red)*				
0—12 . . .	3·78	..	1·00	0·097	0·097	..	10·4
12—24 . . .	4·17	..	0·43	0·057	0·057	..	7·5
24—36 . . .	4·20	..	0·27	0·042	0·041	..	6·6
36—48 . . .	4·12	..	0·17	0·042	0·043	..	4·1
48—60 . . .	4·14	..	0·20	0·039	0·040	..	5·1
			51. *Taliparamba (Red)*				
0—12 . . .	4·66	..	2·078	0·178	0·178	..	11·8
12—24 . . .	4·45	..	1·277	0·098	0·098	..	13·0
24—36 . . .	4·37	..	0·570	0·056	0·054	..	10·4
36—48 . . .	4·33	..	0·552	0·050	0·052	..	10·8
48—60 . . .	4·16	..	0·33	0·034	0·034	..	9·8
			39. *Rangpur (Grey and pink)*				
0—12 . . .	5·69	..	1·43	0·105	0·102	..	13·8
12—24 . . .	5·83	..	0·63	0·049	0·049	..	12·9
24—36 . . .	5·96	..	0·09	0·017	0·012	..	6·5
36—48 . . .	5·97	..	0·02	0·009	0·009	..	2·3
48—60 . . .	6·06	..	0·02	0·009	0·009	..	1·9

KANKAR COMPOSITION AS AN INDEX OF THE NATURE OF SOIL PROFILE*

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(Received for publication on 5 May 1945)

(With Plates XXII and XXIII and one text-figure)

To any one who has had an opportunity of studying the soil profiles of Indo-Gangetic alluvium, and more particularly the ' Bhangar ' i.e. the older alluvium the presence of *kankar* nodules or concretions of varying size, shape and colour must present a characteristic feature. Similar variations in shape and size of lime nodules occurring in Tshernozems (Russia) have been reported by Kassatkin and Krasyuk [1917] †.

An examination of a number of soil profiles in the South East Punjab indicated that the size, shape and colour of *kankar* and other concretions had some relation to the nature of soil profiles. The process of leaching by rain water and attendant *kankar* formation is not likely to affect $CaCO_3$ only, but depending on the prevailing conditions, other constituents, e.g. magnesia, iron, manganese phosphorus, etc., may also be affected more or less.

The nature of climate and of the soil profile determines the conditions of leaching, and thus the nature and amount of constituents mobilized should bear some relationship with the nature of climate and soil profile. Further, these mobilized constituents will get deposited in the profile in its lower layers, because of a change in soil properties. This deposition may occur either along with $CaCO_3$ in the *kankar* concretions or as separate concretions like ferromanganiferrous ones, or rarely even as limy ferruginous concretions. For example, under conditions of lateritic weathering silica is mobilized and may be deposited in the lower layers of soil with high $CaCO_3$ and comparatively lower pH, whereas under conditions of podzolic weathering, more particularly under conditions of poor aeration, sesquioxides are affected. It follows that *kankar* from soil profiles of varied nature might vary in composition accordingly, and that its composition would bear some relationship to the nature of soil profile. This paper reports the results of an investigation carried out to elucidate these points.

Very little work has been done on *kankar* composition so far ; while the relationship of its composition to nature of the soil profile has not been studied at all. However, a lot of work on composition and relation with nature of soil profiles for secondary formations in Podzols (i.e., ortsteins, ferruginous concretions) has been reported, notably by Bennet and Allison [1928], Winters [1938], Drosdoff and Nikiforov and Beater [1940]. Composition of *kankar* has been given by Oldham [1891], in the Annual Report of the Dry Farming Research Station, Sholapur (1935), by Gillam [1937], and Beater [1940]. Wadia and co-workers [1935] have given a detailed bibliography on *kankar* composition, etc.

The present work comprised a study of the differences in chemical composition and physical properties as affected by soil stage or phase of *kankar* soil profile, climate, soil type, texture of the mother soil, depth at which it occurs in the profile and size of the *kankar*.

Materials and methods

Kankar samples were collected from the typical *kankar* soil profiles from Rohtak district, from *kankar* profiles from Lyallpur, Ferozepur, Beas and Jullundur in the Punjab, from Kankather and Deoria in the United Provinces, from black cotton soils from Sholapur (Bombay Presidency) and Indore (Central India), from Bahrein (Persian Gulf), and from a number of other sites.

Concretions and nodules retained on 1 mm. sieve were well soaked with water to loosen the adhering soil and washed till thoroughly clean. These were finally washed with distilled water, dried in the sun, weighed and reported on total weight of air dry soil.

* Part of a thesis submitted for partial fulfilment for the degree of M.Sc. by the junior author

†Cited by Joffe, J. S. (1936). *Pedology*, 53

1. *Physical properties*

(i) *Size distribution.* It was determined by sieving the samples through sieves of square holes of $1\frac{1}{2}$ in., $\frac{5}{8}$ in., $\frac{1}{4}$ in. and round holes of 3, 2 and 1 mm. diameter, and weighing the fractions retained on each.

(ii) *Real density.* It was determined by weighing the unpounded sample in air and under benzene: before weighing in benzene, the sample was left under benzene in a vacuum desiccator to let the liquid penetrate. The results were checked by using a powdered sample and the usual specific gravity bottle.

(iii) *Apparent density.* A method for determining apparent density involving the use of a thick lubricating oil (C oil or gear oil) was used for the purpose. The determination was made on the sample used for real density after benzene had completely volatilized.

(iv) *Moh's hardness number.* It was determined as described by Merril [1897].

(v) *pH value.* It was determined by glass electrode.

2. *Chemical properties*

(i) *HCL extract analysis.* The Agricultural Education Associations method [Wright, 1939] was used. Additional quantity of the acid required to decompose carbonates was allowed for.

(ii) *Ultimate analysis.* The A.O.A.C. [1940] method was followed, excepting that sodium carbonate used was about half the quantity of *kankar* samples taken, as given by Scott [1925] for cement analysis.

(iii) *Free sesquioxides.* These were determined by Drosdoff and Truog's method, as described by Ray Chaudhri and Sulaiman [1940].

Experimental

A. *Effect of stage of soil profile development.* During the collection of the *kankar* samples, it was noted that some of them were soft, whereas others very hard. Accordingly hardness number and compactness were determined in samples of unpounded *kankar* from the different stages* of soil profile development. As a measure of compactness, pore space was calculated from data of real and apparent density. The results are given in Table I.

TABLE I

Physical properties of kankar

Property					Total	Average
	Young profiles					
	IIIA.	IIIB.				
Hardness	1·0	0·5			1·5	0·75
Pore space	13·85	25·20			39·05	19·52
	Immature profiles					
	IB(i)	IB(v)	IC(i)	IC(iv)		
Hardness	2·0	3·0	4·0	6·0	15·0	3·8
Pore space	10·34	10·82	7·76	21·24	50·18	12·55
	Semi-mature profiles					
	IB(ii)	IB(iv)				
Hardness	7·0	7·0			14·0	7·0
Pore space	5·52	2·08			7·60	3·80
	Mature profiles					
	IA(i)	IC(iii)	IE			
Hardness	6·5	7·5	7·00		21·0	7·0
Pore space	2·05	4·26	4·48		10·79	3·60

*Stage of development of soil profile refers to the amount of leaching, as determined by distribution of $CaCO_3$ in the profile; young profile is that in which practically no leaching is perceptible, Immature shows depletion of $CaCO_3$ from horizons overlying *kankar*. In the case of semi-mature profile, the horizons overlying *kankar* have almost lost the whole of $CaCO_3$, whereas the mature profile is absolutely devoid of $CaCO_3$ till *kankar* appears.

It may be seen that *kankar* becomes harder and less porous till the semi-mature stage of soil profile is reached, i.e. when the horizons overlying *kankar* horizon have lost $CaCO_3$ completely. No further change is noted in samples from the later stages of soil profile. When we examine the individual figures we find that sample No. IC (iv), though bearing large pore space (21·24) has a hardness number of 6·0. This may be explained due to its being dolomitic in character.

To find out the composition of these different types of *kankar*, both ultimate analysis and hydrochloric acid extract analysis were carried out and the data for typical samples are presented in Table II.

TABLE II

Ultimate analysis of typical kankar *samples*

Percentage on air dry sample

Stage of soil profile	Depth of occurrence	Loss on ignition	SiO_2	Fe_2O_3	P_2O_5	Al_2O_3 and TiO_2	Mn_2O_3	CaO	MgO
Immature	14-29 in.	27·19	29·84	3·65	..	7·95	0·04	28·52	1·47
Semi-mature	14-29 in.	22·71	30·10	2·17	..	9·73	0·10	30·54	2·58
Mature	64-69 in.	26·18	28·48	3·35	..	6·60	0·10	31·02	2·16
Degraded*	30-42 in.	7·59	55·27	19·27	0·84	11·64	2·18	0·75	0·65

Hydrochloric acid extract analysis

	Moisture	CO_2	Insoluble residue	Soluble silica	Fe_2O_3	P_2O_5	Al_2O_3	Mn_2O_3	CaO	MgO	K_2O	Na_2O	$CaCO_3$† Equivalent	$CaCO_3$† Calculated
Immature	(14-29 in.)0·25	23·73	36·77	0·27	2·44	0·07	4·67	0·04	28·34	1·82	0·25	0·43	53·95	50·60
Semi-mature	(14-20 in.)·028	22·71	38·06	0·31	2·32	0·07	3·33	0·10	31·36	1·64	0·25	0·35	51·65	55·92
Mature	(64-69 in.)0·48	24·02	33·91	0·85	2·72	0·06	2·69	0·10	29·99	2·01	0·22	N.D.	54·61	53·55
Degraded	(30-42 in.)2·45	*Nil*	65·81	0·18	15·92	0·84	8·08	1·96	1·12	1·38	0·58	0·39	*Nil*	2·00

*The samples are in fact ferro-manganiferrous concretions, and cannot be called *kankar*. These have been included to serve as a contrast in composition of the two types of secondary formations.

†Equivalent is that computed from percentage CO_2 of the sample assuming that the whole of it has been derived from $CaCO_3$. Calculated figures have been worked out from percentage CaO, assuming that all of it is present as carbonate.

It may be noted that the different types do not show any systematic change. The mother soil‡ in the case of these samples varied from light loam to heavy loam. Since *kankar* has been formed by redeposition of $CaCO_3$, etc., with the mother soil, the nature of the mother soil would affect its composition a great deal. It was thus felt necessary to analyse the mother soil for the samples of *kankar* studied.

For a comparison of composition of sample from the different stages of soil profile development on a uniform basis, the effect of varied nature of mother soil should be accounted for. Since *kankar* has been formed under conditions of abundant supply of $CaCO_3$, there are very little chances of SiO_2 being mobilized and its being deposited in the lower layers. This is also the opinion of Sigmond [1938] and Merril [1897], who maintain that in the formation of soil from limestone rock, silica is not lost. It was thus felt that the amount of mother soil used in the formation of *kankar* samples could be calculated from SiO_2 content of the two by the following formula :

$$\text{Percentage of mother soil in } kankar = \frac{\text{Percentage of } SiO_2 \text{ in } kankar}{\text{Percentage of } SiO_2 \text{ in mother soil}} \times 100.$$

Thus if the analysis of *kankar* and mother soil is known, the constituents other than those derived from mother soil that go to form various samples can be calculated by subtracting the constituents supplied by the mother soil from the percentage composition of *kankar*. The detailed results are not given, but the balance of constituents thus calculated is given for all the samples in Table III.

‡This term has been used after Bennet and Allison [1928] to designate the soil in which *kankar* was found embedded.

Table III

Balance of kankar *constituents. Based on SiO_2 percentage of* kankar *and mother soil*

Percentage of air dry sample

Serial No.	Profile	Stage	Moisture	CO_2	Insoluable residue	Fe_2O_3	Al_2O_3	P_2O_5	Mn_2O_3	CaO	MgO	K_2O	Na_2O
1	IA (iii)	Immature	—0·27	22·73	0·0	1·47	*Nil*	0·01	0·01	29·65	..	0·25	..
2	IB (i)	,,	—0·37	19·17	0·0	0·23	1·54	0·003	0·02	23·11	0·20	..	..
3	IB (v)	,,	—0·08	18·83	0·0	1·69	0·[illegible]4	0·003	0·01	23·00	1·18	0·02	0·11
4	IC (iv)	,,	..	18·48	0·0	0·76	1·38	0·024	0·03	13·60	8·55	0·22	0·05
5	IB (ii)	Semi-mature	..	21·57	0·0	0·94	2·64	0·000	..	28·18	2·00	..	..
6	ID	,,	0·00	23·48	0·0	0·90	0·31	0·026	..	30·63	0·69	0·07	0·09
7	IB (iv)	,,	0·05	21·08	0·0	0·59	1·63	..	..	27·37	..	..	..
8	IA (i)	Mature	0·19	23·07	0·0	1·45	1·04	0·029	0·08	28·98	1·77	—0·15	N.D.
9	IA (ii)	,,	—0·28	31·00	0·0	1·08	0·[illegible]2	0·014	0·12	43·15	..	0·07	..
10	IA (iv)	,,	—0·32	25·22	0·0	1·02	1·54	0·074	0·10	33·29	1·08	0·09	0·06
11	IE	,,	0·09	31·60	0·0	1·12	0·35	..	..	40·37	0·67	..	..

It may be noted that in addition to the obvious accumulation of carbonates, calcium and magnesium in all the samples, accumulation of iron and phosphate tends to increase with maturity of the profile, but the evidence is in no way conclusive.

B. *Effect of climate and soil type on composition of* kankar. The role of climate in the formation of soils is now well recognized. Glinka [1914] has mentioned the formation of a similar soil from parent materials differing as widely as loess and granite. It was felt that since *kankar* is a secondary formation formed in the soil, differences in climate would affect its composition. Samples of *kankar* from different soils and climates were analysed and the data together with that reported in literature are given in Table IV. As a criterion of climate, Meyer's N : S quotient [Singmond, 1938] is given in the first column.

The effect of the soil type is clearly seen in Table IV. One of the Bahrein samples contains 0·48 per cent SO_3 as gypsum, while the other as much as 19·1 per cent. In contrast with this sample, the sample from a slightly gypseous profile (percentage of $CaSO_4 = 1{\cdot}8$) from Rohtak does not contain any gypsum, presumably because of less dry climate (N : S quotient 13 and 47 respectively).

Table IV

Composition of kankar (*lime concretion*) *samples from different climate and soil types*

Percentage on air dry samples

Locality	N. S. Quotient	Moisture	CO_2	Insoluable residue	Fe_2O_3	P_2O_5	Al_2O_3 TiO_2	Mn_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	$CaCO_3$ Equivalent	$CaCO_3$ Calculated
Bahrein (*a*)	13·3	0·86	31·27	16·16	1·77	0·055	1·83	0·03	42·47	1·69	0·40	0·30	0·48	71·08	75·84
Bahrein (*b*)	13·3	N.D.	14·81	11·84	0·32	0·023	0·82	..	33·59	0·73	0·30	2·76	19·13	33·66	59·98
[1] Lyallpur	40·6	0·55	29·60	19·11	4·18	..	5·96	0·11	37·05	2·44	0·42	0·23	*nil*	67·23	66·16
Ferozepur	..	0·27	26·19	32·29	1·65	0·060	1·85	..	34·36	1·14	0·31	0·09	,,	59·53	61·37
Rohtak	46·9	0·48	24·02	33·91	2·72	0·060	2·69	..	29·99	2·01	0·22	N.D.	,,	54·61	53·55
[1] Do.	46·9	..	..	28·48	3·35	..	6·60	0·10	31·02	2·16	0·52	0·23	,,	..	..
Dolomitic	46·9	0·39	20·36	44·09	2·64	0·060	4·45	0·04	15·16	10·30	0·33	0·45	,,	46·27	27·07
Beas	..	0·75	31·91	19·08	1·85	..	2·59	0·03	40·87	1·10	..	..	,,	72·50	..
[1] Jullundur	..	0·89	22·76	25·40	9·44	..	2·84	0·22	29·49	1·35	..	..	,,	51·75	52·67
Deoria (U. P.)	192·4	0·57	24·58	29·22	2·13	0·04	0·04	0·23	32·65	2·03	0·44	0·23	,,	55·90	58·33
Indore (white)	96·4	..	31·02	15·84	2·02	0·033	2·82	0·41	40·08	0·89	0·42	0·36	,,	70·50	71·59
,, (black)	96·4	1·26	35·64	9·48	1·96	0·033	2·58	0·41	46·31	0·81	0·26	0·15	,,	81·00	82·74
Bijapur	57·0	..	N.D.	7·06	15·97	0·08	5·97	N.D.	36·63	0·29	0·38	N.D.	N.D.	..	65·40
Moody and Crofton Series (U. S. A.)	..	..	..	16·0	..	..	..	..	44·9	1·40	..	..	..	83·7	81·0
[1] Mt. Edgecombe (S. Africa)	225·4	1·44	23·0	27·76	5·00	0·06	1·95	0·09	31·45	1·54	0·58	0·22	..	52·3	56·1
[1] Matanzas (Cuba)	250·0	1·65	1·22	15·60	46·38	0·20	18·15	0·85	2·79	0·46	0·26	1·65	..	2·77	4·98

[1] Results of fusion analysis. For purposes of comparison of HCl extract and fusion analysis, results for Rohtak samples by the two methods are given.

The other two Rohtak samples coming from calcareous and dolomitic profiles respectively show a corresponding difference in their CaO and MgO content. The dolomitic sample contains as much

as 10·30 per cent MgO as compared to 2·16 per cent for limy sample. The limy ferruginous sample from black cotton tract (Bijapur) has a high iron content (16 per cent Fe_2O_3) and also of $CaCO_3$ [65 per cent and very little of SiO_2 (7 per cent)], whereas the Indore limy samples (both black and white) are very poor in iron and silica and much richer in carbonates (85 per cent). The sample from Moody and Crofton series (U. S. A.) contains much more of carbonates and presumably very little of iron. The Mt. Edgecombe sample, though similar to the Rohtak sample in many respects contains much less of alumina. Lastly the sample (Perdigon as Bennet and Allison call it) from Cuba is seen to be highly rich in iron (46·4 per cent Fe_2O_3) but very poor in silica (15·6 per cent) and carbonates (1·2 per cent). In fact the mother soil is richer in carbonates (3·6 per cent) than the concretions.

In general it may be said that as N : S quotient increases, percentage of Fe_2O_3 in concretions increases.

C. *Effect of texture of the mother soil.* While taking *kankar* samples from soil profiles of different texture, a great difference in size and shape was noted. Determination of the size distribution of a few *kankar* samples was carried out and the data are presented in Table V.

TABLE V

Determination of the size distribution of kankar

Profile	Percentage in mother soil		Percentage of *kankar* sample retained on sieves						Calculated specific surface
	Clay	Silt	1½ in.	⅝ in.	¼ in.	3 mm.	2 mm.	1 mm.	
IH Deoria	11·0	15·2	47·5	14·8	18·9	16·2	2·0	0·5	167·8
IF Jullundur	13·7	42·7	..	37·4	37·9	22·9	2·5	0·4	246·3
IB IV Rohtak	11·0	30·8	13·0	54·0	25·4	7·5	0·1	..	135·1
IA (i) Do.	6·5	20·5	..	54·5	47·0	2·5	..	..	151·5
IB (ii) Do.	10·7	24·0	..	22·3	51·1	23·2	1·0	2·4	277·9
Ib (i) Do.	17·2	32·5	..	3·3	74·5	21·4	0·3	0·5	266·2
IC Lyallpur	32·1	28·0	..	..	..	71·8	15·2	13·0	676·8
IA (ii) Rohtak	30·0	52·0	..	..	19·8	74·8	4·8	0·7	455·2

In Table V specific surface per 100 gm. of *kankar* sample is given in the last column, and provides a single value for the size distribution. It is low in the case of preponderantly coarse samples, and high in the case of small sized samples. It may be seen that specific surface is low in case of samples from light textured mother soils and vice versa. Correlation coefficient (r) of specific surface with clay per cent in mother soil comes to + 0·929 (expected value at 1 per cent =0·765), indicating very high relationship.

Samples from heavy textured mother soil are conchoidal, elliptical to spherical in shape and no marked change of shape with increase in size is noted ; whereas samples from light textured mother soils were found to present a great deal of difference in shape with increase in size (Plate XXII, fig. 2). The large pieces are much more angular (locally called '*bichhwa*' or scorpion type because of their appendages) and have many holes permeating them (Plate XXII, fig. 1).

It was felt that the difference in texture of the mother soil would affect the composition of *kankar*. It may be that soil particles of different texture require different quantities of calcium carbonate for their being cemented together. Since percentage of sesquioxides, P_2O_5, manganese, etc. in

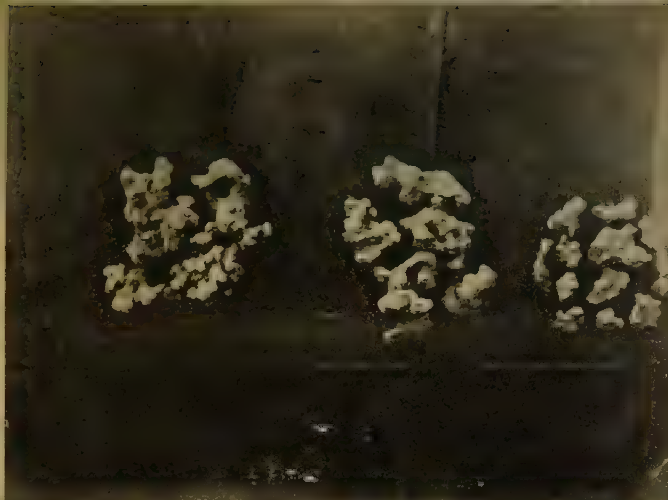


FIG. 1. *Kankar* samples (Scorpion type) of different sizes. It is seen that the larger pieces have holes permeating them.

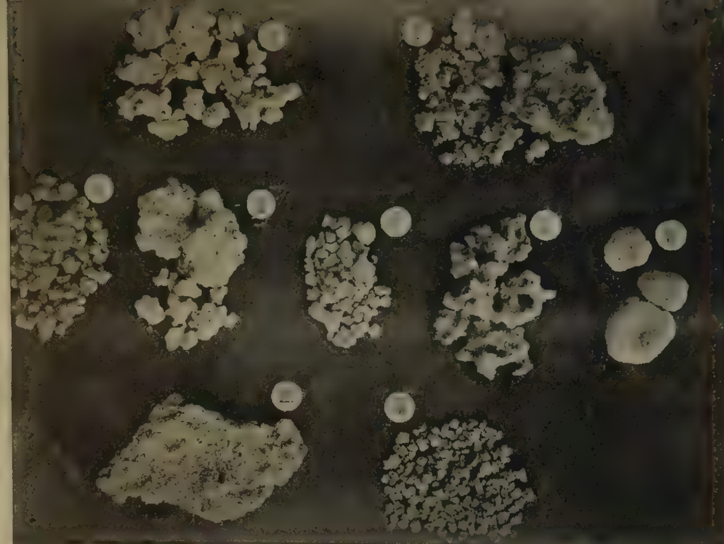


FIG. 2. Different samples of *kankar* (lime concretions) I-IB (i); II-IF (i); III-IE; IV-IH; V-IA (ii); VI-IA (i); VII-IIIA (i); VIII-IE (ii); IX-IG.

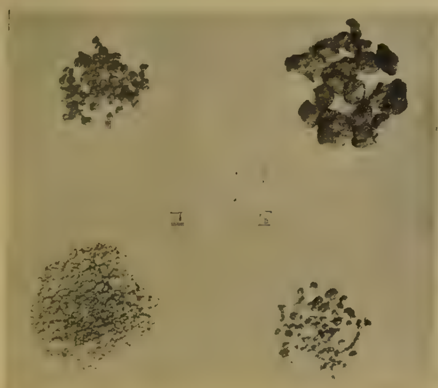


FIG. 3. Limy ferruginous and ferro manganiferrous concretions $\times \frac{1}{4}$ approximately

I—Fe Mn concretions III—Ca Fe concretions

II— do IV— do

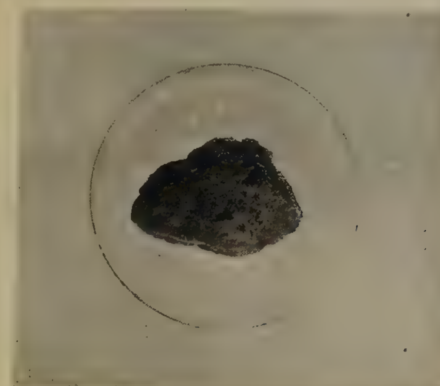
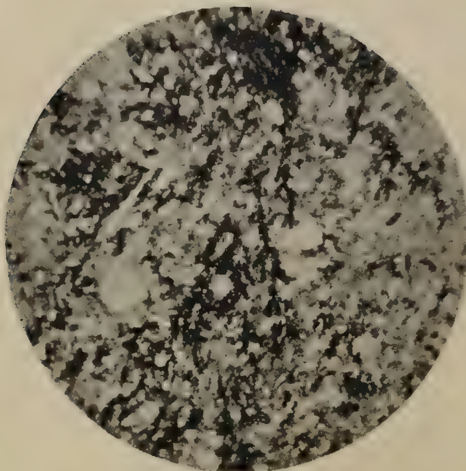


FIG. 4. A piece of mature *Bhata* (slab) type of *kankar* from Kankather (U.P.) showing the deposition of free iron and manganese as spherical deposits $\times \frac{1}{4}$ approximately.



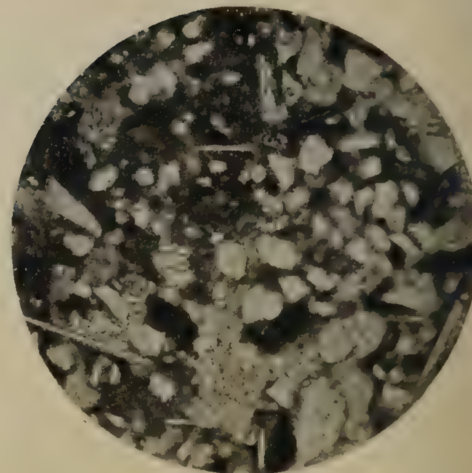


FIG. 1. Microphotographs

1K [IA(i)—Mature] × 62 7K [IB (i)—Immature] × 57

Q—Quartz ; Ca—Calcite ; Mu—Muscovite ; Bi—Oxidized Biotite

clay—Ca——Clay-calcite

FIG. 2. *Bhata* (slab) type of *kankar* × ¼

kankar are greatly affected by climate, maturity of soil profile, etc., it was thought proper to compare samples from the same climate. The results for such a comparison are presented in Table VI.

TABLE VI

Effect of texture of mother soil on composition of kankar

Percentage on air dry sample

Locality	Texture of mother soil		Percentage of mother soil	Percentage of *kankar*			
	clay	silt		SiO_2	Fe_2O_3	Al_2O_3	$CaCO_3$
1. Beas (Dist. Amritsar).	2·0	2·5	46·3	36·7	3·7	8·0	48·7
2. Rohtak . .	6·5	20·5	38·7	28·5	3·4	6·6	51·6
3. Rohtak . .	10·7	24·0	46·3	30·1	3·2	7·7	51·6
4. Rohtak . .	25·9	37·2	35·3	23·2	4·0	5·8	60·0
5. Rohtak . .	30·0	52·5	18·4	12·3	1·9	4·6	73·4
6. Beas . . .	27·6	38·8	20·6	14·0	4·0	5·4	72·5

A progressive increase of carbonates with increase in clay content of the mother soil is noted. Correspondingly percentage SiO_2 content of *kankar* goes on decreasing with the heaviness of texture of the mother soil. Percentage of mother soil, in general, is low in samples from heavy textured mother soils and high in samples from light textured mother soil. The figures for iron and alumina do not warrant any general remarks. Correlation coefficient (r) of percentage of $CaCO_3$ in *kankar* samples with clay content of the mother soil works out to + 0·842 indicating very high significance, expected value at 1 per cent being 0·699.

D. *Effect of size.* To study how variation in size of *kankar* affected its composition, different fractions (above $1\frac{1}{2}$ in., $\frac{5}{8}$ in., $\frac{1}{4}$ in., 3 mm. and that below 2 mm.) of two samples of *kankar* from profile IB and IA were analysed for their HCl extract. The results are subjoined in Table VII.

TABLE VII

Effect of size on kankar *composition*

P-IB (iv)	Moisture	Insoluble residue	CO_2	Fe_2O_3	Al_2O_3	CaO
Above $1\frac{1}{2}$ in.	0·36	38·44	24·34	2·06	4·56	28·84
$1\frac{1}{2}$-$\frac{5}{8}$ in.	0·36	40·56	22·08	2·16	4·74	28·00
$\frac{5}{8}$-$\frac{1}{4}$ in.	0·55	36·58	23·16	1·99	4·85	29·95
$\frac{1}{4}$in.-3 mm.	0·36	34·24	24·32	2·13	4·61	32·48
Below 2mm.	..	..	19·07	..	..	..
P-IA (ii)						
Above $\frac{5}{8}$ in.	N.D.	40·23	21·62	1·67	4·45	28·55
$\frac{5}{8}$-$\frac{1}{4}$ in.	..	41·07	21·62	1·36	4·48	29·39
$\frac{1}{4}$in.-3 mm.	..	42·14	21·23	1·81	3·57	29·11
Below 2 mm.	..	..	18·34	..	..	..

It may be noted that the different fractions, except that for below 2 mm., do not differ materially in composition. Fraction below 2 mm. was obtained by sieving the powdered soil under water on a 100 mash sieve, and cleaning the sample retained on the sieve from coarse sand and mica. The low carbonate content of this fraction is possibly due to contamination with sand.

E. *Nutritive aspect of* kankar. That plant roots excrete carbonic acid, and under conditions of poor aeration even organic acids, etc., is well known [Miller, 1939]. In view of the fact that *kankar* contains appreciable quantities of nutrients (0·03- 0·09 per cent P_2O_5 and 0·15 to 0·47 per cent K_2O), and further that these are at least in part soluble in water charged with carbonic acid, an estimate of the solubility of various constituents of different *kankar* samples in CO_2 water was undertaken. Three samples of *kankar* and one of ferro-manganiferous concretions were placed in gooch crucibles and leached with CO_2 water at 35°C. (0·12 per cent by weight) till almost free of calcium. The results of analysis are given in Table VIII.

TABLE VIII

Composition of CO_2 water leachate of kankar *sample*

—	Parts per million.			Fe.Mn. concretions
	Mature	Mature	Mature dolomitic	
Fe_2O_3	2·88	0·60	0·36	0·70
P_2O_5	0·20	0·06	0·02	0·14
CaO	495·6	264·5	35·0	28·9
MgO	5·0	1·5	30·0	2·5

The results show that some of the samples give appreciable quantities of nutrients and are thus of use to crop. It is interesting to note that the Fe.Mn.concretions yield comparatively small amount of P_2O_5 in view of the fact that it has 0·84 per cent P_2O_5.

F. *General. Kankar* has a *p*H of 8·2 to 9·0 and is non-magnetic. It does not contain any appreciable organic matter, as evidenced by action of hydrogen peroxide. Even the ferro-manganiferrous concretions are non-magnetic and devoid of organic matter. Their *p*H is 7·0 to 7·2.

DISCUSSION

1. *Nature of* kankar. The use of word '*kankar*' or '*kunkur*' to designate concretions or nodules of lime carbonate found in India is well recognized [Sigmond, 1938; Hilgard, 1930]. In practice, however, this term is applied for various kinds of formations in the soils, e.g. lime nodules, lime concretions, lime stone slabs locally called *bichhwa*, *kankar*, *ror* and *bhata* respectively.

These formations may be said to be the different types of *kankar*. A photo of these together with other types of *kankar* studied is given in Plate XXII, fig. 2 and Plate XXIII, fig. 2.

On the basis of physical and chemical characters for these samples, reported earlier, and micro-photographs (Plate XXIII, fig. 1), one may say that *kankar* is essentially a mixture of 50-75 per cent of lime carbonate (or at times lime and magnesium carbonate) with 13-57 per cent of soil in which it is formed. These together with varying amount of free sesquioxides, P_2O_5, Mn_3O_4, etc., form a concretionary or nodular body. It is definitely of the nature of a secondary formation as distinct from impure lime stone. In consistency it is soft (Moh's hardness No. 1-3) in the initial stages of formation and becomes hard (hardness No. 7) with maturity.

Gillam [1937], in his description of the lime concretions of Moody and Crofton series, has mentioned that they are annular in structure. The micro-photographs of *kankar* samples (Plate XXIII, fig. 1), however, do not exhibit this structure. These photos further show that calcium carbonate (calcite) has deposited round quartz, clay and other minerals in rather an irregular manner and has

cemented the whole mass. This structure suggests the deposition of calcium carbonate in pores, cavities, channels, etc., through which water movement in the liquid state took place.

2. *Relationship of* kankar *type and percentage of carbonates of mother soils.* Looking up the characters of mother soils for all *bhata* (slab type) and *bichhwa* (scorpion) types of *kankar* samples from Rohtak district, they are found to contain the following quantities of carbonates :

Kankar type	Average percentage of carbonates	No. of samples
Bichhwa	6·40	20
Bhata	23·85	4

The above data point out that slab type of *kankar* develops in soils with very high percentage of $CaCO_3$—about 24. This may be due to the fact that the initially large percentage of carbonates, supplemented by leached carbonates received in the non-capillary pores, is enough to cement the whole mass and transform it into *kankar*. It may be stated that *kankar* contains about 50-60 per cent of carbonates. However, several other factors may be involved. Another significant difference between the mother soils of two types is that those giving slab type are richer in magnesium carbonate.

3. *Porosity of* kankar *as an index of the stage of soil profile.* In the initial stages of *kankar* formation, calcium carbonate deposited is more or less loose. It gets compact either by inclusion of fresh $CaCO_3$, sesquioxides, etc., with the progress of the process, or only by pressure or by both. It follows, therefore, that the percentage of pore space in *kankar* should bear a relationship to the stage of soil profile. It is seen from Table I that the percentage of pore space in *kankar* goes on decreasing till the soil profile becomes semi-mature, after which there is no change.

As $CaCO_3$ in the horizons overlying *kankar* becomes lower by progressive leaching, the stage of a soil profile is related with the amount and distribution of $CaCO_3$ in the profile. The young and immature profiles have lot of carbonates in the horizons overlying *kankar*, whereas the more mature ones do not have any in the horizons overlying *kankar*. Percentage of pore space in *kankar*, therefore, should bear a relationship with percentage of carbonates of the overlying horizons. When the two sets of data are studied it is seen that in general pore space in *kankar* decreases as the percentage of $CaCO_3$ of the horizons overlying *kankar* becomes lower. Thus it may be said that porosity of *kankar* is a fairly good index of the stage of soil profile.

4. *Depth of* kankar *horizon.* Depth of *kankar* horizon is found to vary widely even at places small distances apart. Wyssotski [1899] and Hilgard [1930] believe this depth indicates the depth of penetration by rain water. Shantz [1923] thought it to be the region of desiccation of moisture by plant roots. Gillam [1937] has discussed the whole problem and maintains that the percentage of $CaCO_3$ in the profile is a major factor. A profile with a high content of calcium carbonate will develop the horizon higher than one with a relatively low percentage of $CaCO_3$ due to the ability of the former to saturate the leaching water with $CaCO_3$ at a much higher level. The various factors controlling the depth of the horizon may be grouped as under :

1. Depth of infiltration of water.
2. Percentage of $CaCO_3$ of the profile.
3. Depth of the layers desiccated.

In the profiles examined there is evidence of all these factors affecting the depth of *kankar* horizon. The available data for a few profiles are depicted in columns drawn for each profile (Fig. 1). No single factor explains all the results. The problem, however, is a very complicated one, and more data are required to make any definite observation.

5. *Factors affecting chemical composition of* kankar *under the same climate.* From a consideration of the process of *kankar* formation, it may be concluded that as 13-57 per cent of *kankar* is mother soil, its (mother soil's) composition should affect *kankar* composition. A reference to results of the analysis of mother soils and respective *kankar* samples shows that a relationship does exist.

As examples, it is seen that the dolomitic soils give rise to samples rich in magnesia. Further, the colour of the *kankar* sample is similarly influenced by that of the mother soil.

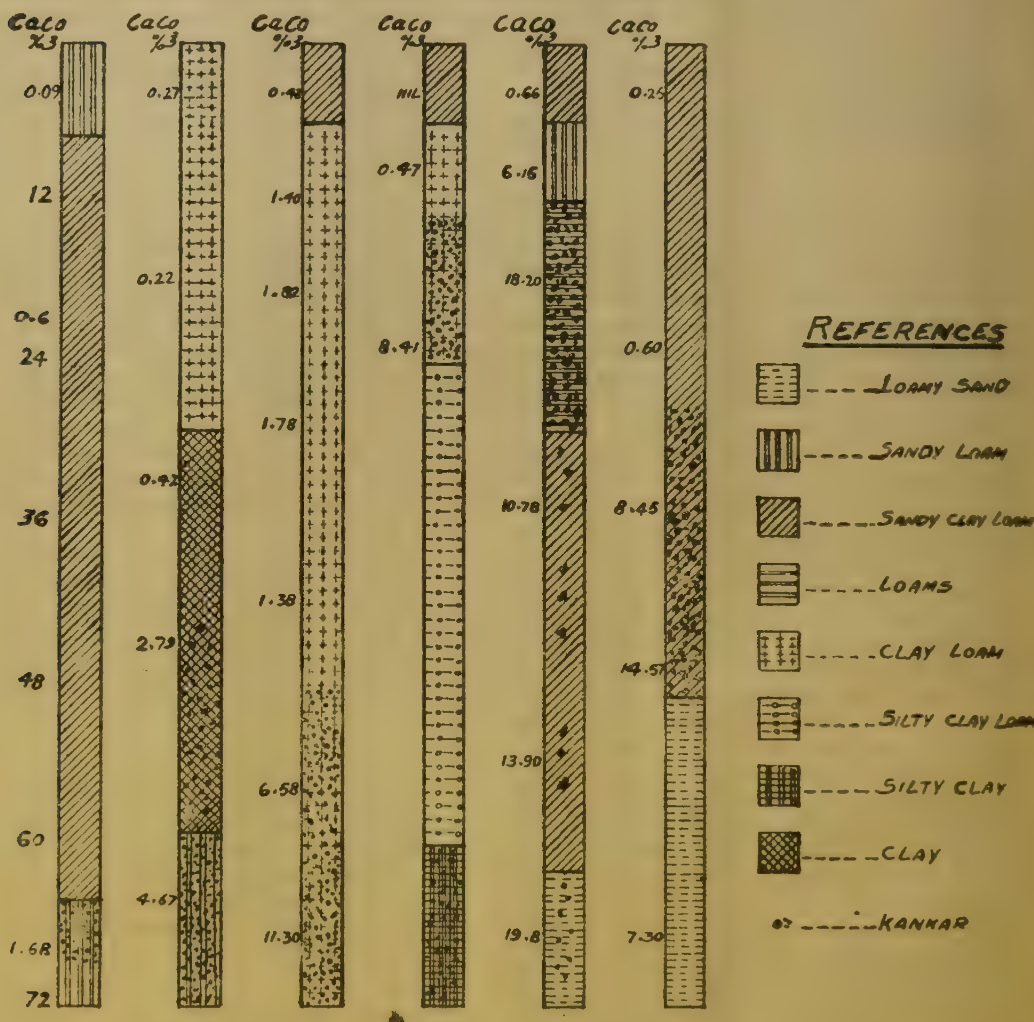


FIG. 1. Depth of *Kankar* horizon and soil characters

That *kankar* contains much larger quantities of carbonates than the mother soil needs no mention. This large percentage of carbonates in *kankar* affects the gross percentage figures of other constituents, and a comparison of other constituents with those of mother soil containing comparatively much less carbonates is not sound. To compare the composition of the mother soil and *kankar* regardless of carbonates, these should be expressed as percentage on carbonate free material. The results of such a comparison are set forth in Table IX.

Table IX

A comparison of the composition of mother soils and respective kankar *samples*

Percentage on carbonate free material

Serial No.	Profile	Stage	Moisture	Insoluble residue	Fe_2O_3	Al_2O_3	P_2O_5	Mn_2O_3	CaO	MgO	K_2O	Na_2O	
1	Lyallpur	Young	1·55	77·74	6·59	7·15	0·474	1·100	12·06	2·61	1·35	0·75	*Kankar*
			1·55	81·34	4·92	5·90	0·154	0·038	0·98	1·57	..	0·64	Mother soil
2	Rohtak	Immature	0·54	79·84	5·30	10·14	0·152	0·091	*Nil*	..	0·54	0·93	*Kankar*
			1·55	80·16	4·39	6·82	0·147	0·060	..	3·60	0·40	0·20	Mother soil
3	Rohtak IB (v)	,,	1·76	81·68	6·59	8·68	0·100	0·459	..	2·73	0·61	0·50	*Kankar*
			1·94	81·93	2·93	8·61	0·103	0·039	..	1·99	0·57	0·41	Mother soil
4	Rohtak IB (iii)	Semi-mature	1·08	79·92	7·55	9·06	0·188	0·071	*Nil*	N.D.	0·47	..	*Kankar*
			1·90	77·66	6·05	6·02	0·100	..	..	2·02	0·72	0·39	Mother soil
5	Rohtak IB (ii)	,,	..	62·25	6·55	15·07	0·150	0·196	4·30	5·33	..	..	*Kankar*
			..	69·23	4·71	14·96	..	..	0·89	1·43	..	..	Mother soil
6	Rohtak IB	,,	0·67	79·78	4·08	4·57	0·150	0·196	0·62	2·82	0·77	0·22	*Kankar*
			0·755	89·20	3·06	4·26	0·094	0·020	0·87	1·31	0·16	0·34	Mother soil
7	Rohtak IA (i)	Mature	1·06	74·87	6·00	5·93	0·150	0·217	..	4·43	0·44	N.D.	*Kankar*
			0·80	85·88	3·44	5·30	0·090	..	..	0·68	1·01	0·40	Mother soil
8	Rohtak IA (ii)	,,	*Nil*	54·87	6·93	4·59	0·074	0·080	8·21	..	0·79	..	*Kankar*
			1·55	80·84	4·18	8·19	0·034	..	..	0·90	0·72	0·28	Mother soil
9	Rohtak Slab Type	Immature	1·18	82·13	5·02	8·08	0·151	..	..	2·28	0·66	0·12	*Kankar*
			..	85·96	3·61	5·24	0·105	0·031	..	2·16	0·39	0·41	Mother soil

Comparing the results of insoluble residue from samples of various stages, we find a small difference (77·7 and 81·3 per cent for *kankar* and mother soil respectively) in the case of young profile (Lyallpur). The samples from immature profiles have practically the same insoluble residue as the mother soil. A progressive lowering in samples from more mature profiles is noted. The two samples from mature profiles have 74·7 and 54·9 per cent insoluble residue as compared to 85·9 and 80·8 per cent respectively of their mother soils. The two slab type samples have practically the same insoluble residue as their mother soils.

All the *kankar* samples are richer in iron than the respective mother soils, the difference varying from sample to sample. The excess is present very probably as free Fe_2O_3 in the form of limonite. The *kankar* samples, in general, contain as much alumina as the mother soil. The slab type sample is, however, found to contain 8·08 as compared to 5·2 in the mother soil. Percentage of P_2O_5 in Lyallpur *kankar* sample (0·474 per cent) is considerably higher than for the mother soil (0·154 per cent). The immature samples contain as much phosphorus as the mother soil, whereas the semi-mature and mature ones higher quantities.

Some of the *kankar* samples are much richer in manganese, samples from mature and semi-mature profiles containing higher quantities. Figures for potash and soda do not show any consistent difference, and the *kankar* samples, in general, contain as much of these constituents as the mother soil. Nothing can be said with certainly about lime and magnesia, as in allowing for a large percentage of carbonates and its distribution as between lime and magnesia in dolomitic samples, a large error creeps in.

In view of the above, it may be said that when *kankar* and mother soil analysis are expressed as percentage on carbonate free material, the two more or less agree in alumina, potash and soda. As regards other constituents, the nature of soil conditions determines their amount, e.g. iron, phosphate and manganese in *kankar* tend to be higher in *kankar* when compared to that in mother soils more particularly for mature profiles. In the case of mature soil profiles, these constituents may some time segregate as ferruginous concretions of the composition given in Table II. Insoluble residue in the case of mature samples is lower than that of the mother soils which cannot be readily explained. It may possibly be due to the preferential mixing of finer particles of mother soil with $CaCO_3$, and as these are less siliceous, the resulting product is also less siliceous.

The formation of spherical or rounded concretions in heavy soils as compared to large irregular and angular nodules in light soils (described previously) is probably due to the difference in size of soil crumbs, pore size, etc. The process of deposition of carbonates in non-capillary pores remains more localized in heavy soils, but spreads round widely in light soils.

To sum up, the composition of *kankar* samples from the Indo-Gangetic alluvium has been found to depend on the following factors:

(i) Texture of the mother soil. Heavy textured soils give rise to higher carbonates and correspondingly less of siliceous matter.

(ii) The composition of mother soil. Its effect may be judged from the fact that when *kankar* composition is expressed as percentage on carbonate-free basis, the figures agree fairly closely with percentage composition of the mother soil on the same basis. The main difference lies in iron, manganese, phosphorous and to less extent in silica. The former exist as free oxides. If due allowance is made for them, a good idea of the composition of mother soil may be had from *kankar* analysis.

To ascertain whether the above constituents exist as free sesquioxides or not, five *kankar* samples and one ferruginous concretions sample were analysed for their free sesquioxides and silica. Due to large percentage of calcium carbonate in the *kankar* samples, the sesquioxides, precipitated as sulphides in Drosdoff and Truog's method, could not be estimated. The data for the ferruginous concretions from a degraded profile from Rohtak are given below:

Experimental			Calculated		
Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3	SiO_2
12·06	0·19	1·00	12·65	2·55	

It may be said, therefore, that at least in the ferruginous concretions, the balance of Fe_2O_3, as calculated from analysis of concretions and mother soil on the basis of SiO_2, exists as free sesquoxides. And probably the same is true about *kankar* as well.

To elucidate the latter point further, sections of four typical samples of *kankar* were prepared examined and micro-photographs of two of them taken by the Director, Geological Survey of India, Calcutta, on request. The relevant extract from his report is reproduced below and the micro-photographs are illustrated in Plate XXIII, fig. 1.

(I) 1K. Kankar (mature—Rohtak). The mineral constituents are quartz up to 0·15 mm. and about 30 per cent of volume of rock; calcite; muscovite; biotite with calcite growing as wedges between the cleavage lamellae; clay matrix; opaque oxides; and hornblende.

(II) 7K. Kankar (immature—Rohtak). The mineral constituents are quartz up to 0·17 mm. averaging 0·08, and about 15 per cent of the volume of the rock; calcite; muscovite; oxidized biotite; much brown semi-opaque oxides probably limonite dendritic opaque oxide possibly pyrolusite and clay matrix.

(III) 15K. Kankar (semi-mature dolomitic—Rohtak). The mineral constituents are quartz up to 0·15 mm. and about 20 per cent of the volume of the rock; calcite; muscovite; hornblende; clay matrix; opaque oxides; probably limonite.

(IV) 20K. (mature—Jullundur). The mineral constituents are quartz averaging 0·05 mm., and about 10 per cent of the volume of the rock ; calcite ; muscovite ; biotite ; scattered opaque oxides ; probably limonite and clay matrix.

'(1) It is seen that free quartz occurs in all the slides. Volumetric estimates are by eye and only approximate.

'(2) No. 7K is exceptional in the presence of much semi-opaque brown oxide—probably limonite and of dendritic opaque oxide—possibly pyrolusite.

'(3) A certain amount of limonite material has developed in all the specimens from the oxidation of biotite.

'(4) It is not possible to determine the nature of the oxides.'

It may be seen that as postulated above *kankar* does contain varying degrees of free oxides of iron and manganese. It is, however, unfortunate that even this method fails to estimate the quantity of free oxides, and thus no direct estimation of the calculated amount has been possible.

The micro-photographs also indicate the probable mode of formation which consists in the deposition of calcite, etc. in between clay matrix and quartz grains.

6. *Effect of climate and soil type on* kankar *composition*. The varied nature of mother soils in different climates and soil types is well known, and since it enters into the composition of *kankar* to varying degrees, a variation of *kankar* composition with these changes may be expected. However, if we compare the mother soil and *kankar* composition on carbonate free material for samples from varied climates and soil types, more fundamental differences are noted. The results of such a comparison are set forth in Table X.

TABLE X

A comparison of the composition of the mother soils and respective Kankar *samples from different climates and soil types*

Serial No.	Locality	Soil types	Meyer's N/S quotient	Moisture	Insoluble residue	Fe_2O_3	Al_2O_3	P_2O_5	Mn_2O_3	CaO	MgO	K_2O	Na_2O	SO_3
				(Percentage on carbonate free-basis.)										
1	Bahrein . .	Desert . . .	13·3	0·72 1·31	84·13 90·54	1·24 1·23	1·40 1·90	0·124 0·100	..	3·05 1·11	3·11 2·0	0·12 10·22	0·51 0·36	0·91 0·60
2	Lyallpur . .	Alluvium . .	40·9	..	77·74 81·34	6·39 4·92	7·15 5·96	0·470 0·154	0·100 0·038	2·06 ..	2·61 5·62	1·35	0·75 0·64	*nil*
3	Ferozepur . .	,, . .		0·67 0·75	79·78 89·20	4·08 2·06	4·57 4·26	0·150 0·094	0·02	0·62 0·87	2·82 1·31	0·77 0·16	0·22 0·34	*nil*
4	Rohtak immature	.. . .	46·9	1·76 1·94	81·68 81·93	6·59 2·93	8·68 8·61	0·100 0·103	0·06 0·05	*nil* ,,	2·73 1·99	0·61 0·57	0·50 0·41	
5	Rohtak mature .	Gypseous . .	46·9	0·64 1·65	67·11 80·40	6·38 4·71	8·76 6·11	0·253 0·094	0·40 0·04	4·16 1·61	3·80 1·48	0·57 0·72	0·42 0·36	Trace 1·18
6	Deoria . . ,, . .	Limy alluvium . Limy ferruginous molten soil	192·4	1·30 5·23 2·83	69·58 58·64 83·42	5·07 14·11 3·66	6·71 10·64 5·19	0·095 0·124 0·062	0·59 .. 0·62	0·48 0·32 1·22	4·83 2·66 2·25	.. 0·64 0·09	0·41 0·53 0·28	*nil*
7	Bijapur . .	Regur . . .	57·9	8·95* 9·24	18·73 63·43	42·38 9·63	15·84 15·39	0·212 0·085	.. ..	2·12 0·61	0·77 0·34	1·01 0·61	N.D. ,,	N.D ,,
8	Indore . .	Limy White . . Limy Black molten soil	96·4	.. 6·63 2·89	53·69 49·89 69·24	6·85 10·31 5·50	13·65 13·57 12·82	0·112 0·174 0·105	0·37 2·18 0·24	2·07 4·58 0·20	3·02 4·26 1·63	1·42 1·29 1·17	1·22 0·81 0·62	
9	Mt. Edgecombe .	Coastal primary .	225·4	3·02 4·24	58·15 68·56	10·47 7·20	4·08 10·65	0·126 0·060	0·19 0·11	4·57 0·43	3·23 0·82	1·21 0·98	0·46 0·47	Trace ,,
10	Matanzas . .	Lateritic . .	250·0	11·67 11·81	16·06 26·63	47·74 31·20	18·66 28·42	0·21 0·17	0·87 0·32	1·60 0·07	0·47 0·42	0·27 0·34	1·70 1·68	N.D. ,,

The lower line reports results of mother soil analysis.
* *Loss on ignition figures.*

It is seen that concretions and mother soil from desert differ only in carbonate content. The Ferozepur and Lyallpur samples from arid climate (Q-40) have practically the same insoluble residue (77·7 and 79·8 per cent) as the mother soil (81·3 and 89·2 per cent), and slightly more of iron, phosphate, manganese. Other constituents do not show any difference.

In contrast with this, the sample from Deoria (Q-192) although derived from a soil profile containing a lot of carbonates in the surface and alkaline reaction, contains much less insoluble residue (69·6 per cent) than the mother soil (83·4 per cent). Iron oxide (5·1 per cent), manganese (0·59 per cent) and phosphorus (0·095 per cent) in *kankar*, too, are greater than what the mother soil has. Further the upper horizon contains 1·69 per cent limy ferruginous concretions which have much more of iron (14·1 per cent), P_2O_5 (0·124 per cent), Mn_2O_3 (6·9 per cent) and even alumina. The *kankar* samples from a mature profile from a more arid climate show similar composition. Further it is seen that *kankar* from even a slightly gypseous soil profile does not contain any gypsum.

The limy ferruginous sample from Bijapur is much less siliceous (18·7 per cent), has a high iron (42·4 per cent) and phosphate (0·21 per cent) content than the mother soil, which has 63·4, 9·6 and 0·085 per cent of these constituents respectively. Analysis of the limy samples is not available but from the description given by Kanitkar *et al.* [1935], it appears to consists entirely of $CaCO_3$ and much less of iron and silica.

Results of comparison for the white and black *kankar* samples from Indore with mother soil also show both the *kankar* samples to be less siliceous (53·9 and 49·9 per cent insoluble residue). Unlike samples of *kankar* from Bijapur or Deoria, the black sample does not contain very high percentage of iron. As pointed already, the white and black *kankar* differ in the former being more siliceous, containing more carbonates and alumina than the black one. Both the white and black *kankar* samples contain more of iron than the mother soil.

The Mt. Edgecombe sample has several features in common with that of the Rohtak samples, e.g. the *kankar* (lime concretion) and mother soil when expressed as percentage on carbonate free basis agree fairly closely except for slightly less silica, higher iron, phosphate, and manganese, but unlike the Rohtak samples the concretions contain much less alumina than the mother soil.

The perdigon samples from Matanzas (Cuba) have been included in the list to serve as an example of the Pedalfer group of soils. The perdigon is less siliceous, has more iron and less alumina than even the mother soil.

If we strike a balance sheet for composition of these concretions from the mother soil analysis on the basis of percentage of mother soil contained in them, the above conclusions are found to hold good.

It is interesting to see that the results arrived at by comparison on carbonate-free basis are substantiated by the results of comparison of SiO_2 basis.

When we review the above in the light of conditions of soil formation, the following remarks may be made :

(*a*) The accumulation of gypsum besides carbonates in Bahrein samples is due to the very low rainfall of the desert area.

(*b*) The accumulation of iron, phosphate, manganese and, of course, of carbonates, is due to decrease of aridity in Punjab samples. As the soil profile becomes mature, *kankar* and mother soil analysis on carbonate-free basis differ, the former containing less silica, more iron, phosphorus, manganese, etc. Sometimes these constituents may segregate as ferruginous concretions or rarely even as limy ferruginous concretions. Under conditions of higher rainfall, the above concretions are met with more abundantly and even in immature soils.

The release of these constituents and their deposition in *kankar* is due to either of the following :

(i) Leaching with CO_2 water in the absence of carbonates and neutral to faintly acid reaction, e.g. degraded profile (IB iii) and mature profile (IA ii).

(ii) Lack of aeration due to excessive moisture in wet season and a possible effect of the decomposition products of organic matter even in the presence of carbonates, e.g. in Deoria, Lyallpur samples, etc.

(iii) The activity of iron bacteria : It has not been possible to estimate their role.

(*c*) The definite accumulation of iron in concretions from regur (Bijapur) is not understood in view of the fact that even the surface soil contains as much as 18 per cent calcium carbonate, and further its distribution in the profile does not indicate any evidence of

leaching. Erosion in this tract is very severe as has been described by Kanitkar and co-workers [1940]. It may be that this is a truncated profile in which the leached horizon (A) has been removed. The decided decrease of silica also cannot easily be explained and may indicate the lateritic tendency in the original profile. More work in this direction is needed.

(*d*) The accumulation of iron and alumina and phosphorus, etc. in Indore *kankar* samples is not well understood. The data kindly supplied by Dr A. Sreenivasan indicated that the soils have been subjected to alkaline hydrolysis. The presence of concretions in the surface and their decrease in quantity with depth suggests that like the Bijapur soil they may also be truncated, and the exposed 'B' horizon has been further subjected to leaching. The small accumulation of alumina is, of course, due to alkaline hydrolysis.

(*e*) A loss of silica in concretions from Mt. Edgecombe may also be explained as a probable consequence of higher rainfall and high temperature, high pH (8·8). As regards loss of alumina in contrast to profiles from Rohtak, a reference to the analysis of soil profiles and the published account of Beater [1941] show that the nature of alumino silicates is probably responsible for the difference. Beater mentions that percentage figures of iron and alumina for HCl extract and fusion analysis of these profiles do not differ. In contrast to this a very great difference of alumina percentage for HCl extract and fusion analysis results has been found for profiles from Indo-Gangetic alluvium.

(*f*) The lateritic type of soil forming processes in Cuba accounts for the decrease of carbonates and silica, and a great increase of iron.

SUMMARY

1. *Kankar*, a hard lime concretion or nodule of the nature of a secondary formation, is met with widely in Indo-Gangetic alluvium and Black Cotton tracts. It presents a variety of shape, size, colour, etc. Results of a study of the relationship between its composition and the nature of its soil profile are presented.

2. *Kankar* consists of 50-70 per cent of $CaCO_3$, and 25-45 per cent of mother soil and a small percentage of free iron oxide, manganese oxide and phosphate, the exact amount depending on the condition of soil profile. In general it consists of 45·3-73 per cent $CaCO_3$, 1·84-4·08 per cent Fe_2O_3, 1·22-5·9 per cent $Al_2O_3 \cdot P_2O_5$, 0·03-0·08 per cent P_2O_5, trace to 0·23 per cent Mn_2O_3, 1·3-10·5 per cent MgO, 0·05-0·47 per cent K_2O, 0·11-0·05 per cent Na_2O.

In certain cases limy ferruginous concretions and ferruginous concretions are formed but the circumstances leading to their formation are not understood. There is a progressive decrease of pore space and increase of hardness of *kankar* with increase in maturity of soil profile.

3. An examination of section of *kankar* samples of different maturity and of their microphotographs confirms the above conclusions regarding the presence of varying amounts of free sesquioxides and Mn_2O_3 in *kankar*. Comparison on SiO_2 basis and carbonate-free basis with the mother soil also confirm the above view point.

4. Texture of the mother soil affects the size, shape and carbonate content of *kankar*. Samples from heavy textured mother soils are smaller in size, semispherical, with no holes penetrating through them and have a relatively high carbonate content (60-70 per cent). Those from light textured mother soils are larger, irregular, angular and with holes penetrating through them and have less of carbonates (50-60 per cent).

5. Analysis of samples of *kankar* and lime concretions from different climates and soil types show fundamental differences. With decrease in aridity there is an increase of iron, phosphorus and manganese. The data point out a relationship of soil conditions with analysis of concretions.

6. Comparison of the composition of these concretions and that of respective mother soils on the basis of carbonate free material brings out the effect of climate and soil type. The changes in compositions are discussed with reference to soil conditions.

7. When the constituents derived from mother soil are accounted for on the basis of silica content, the balance of constituents for the various samples suggests the presence of small amounts of free

iron oxide, manganese oxide, and phosphate. The results for other samples from different soil types confirm the conclusions arrived at by comparison on carbonate-free basis. In view of the above, a study of the composition of secondary formations as an aid in soil genesis is suggested.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to the Imperial Council of Agricultural Research for financing Dry Farming Scheme under which this piece of work was carried out. They also wish to acknowledge thankfully the help given by L. Sukh Dayal, formerly Soil Physicist, Rohtak. They have pleasure in expressing their deep gratitude to the Director, Geological Survey of India, Calcutta, for very kindly undertaking the examination of *kankar* samples and supplying micro-photographs to Dr B. E. Beater of the S. A. Sugar Association Experimental Station, Mt. Edgecombe, Natal, South Africa, for supplying complete data for one profile and lime concretions and to Dr A. Sreenivasan, Agricultural Chemist, Institute of Plant Industry, Indore, for kindly sending samples of *kankar* concretions and mother soil and supplying certain relevant data.

They are also indebted to Rao Bahadur B. Viswa Nath, formerly Director, Imperial Agricultural Research Institute, New Delhi, for permission to carry out certain analytical work in his laboratories.

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REPUTED ABORTIFACIENT PLANTS OF INDIA*†

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(Received for publication on 22 March 1946)

ABORTIFACIENTS are drugs or agents that cause abortion, i.e. the expulsion of the fœtus prematurely, particularly at any time before it is viable, or capable of sustaining life. The gestation period, i.e. the carrying period of the young in the womb from conception to delivery, varies in different animals, and so far as human beings are concerned, the term abortion usually implies the expulsion of the fœtus during the first six months of pregnancy. Expulsion of the fœtus after the

* A considerable amount of work in connection with this paper was done by the late Mr N. C. Goswami, Botanical Assistant in this Inquiry

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sixth month when it is viable, but before the normal period of nine months, is generally termed premature delivery or labour. The popular term miscarriage is usually applied to an abortion before the sixth month, sometimes only in case of abortion between fourth to sixth month, occasionally before the sixth week of gestation, and rarely even to a premature labour. In law, however, the term abortion usually implies criminality in producing miscarriage for an improper purpose at any time of gestation short of full term, and means premeditated or intentional abortion produced by artificial means, solely for the purpose of preventing the birth of a living child ; it is designated as criminal abortion.

For the purpose of this paper abortion may be divided into three categories, viz. (*a*) natural abortion, (*b*) artificial abortion, and (*c*) criminal abortion or fœticide.

(A) Natural abortion

The causes responsible for naturally occurring cases of abortion are various. They may be due to the poor condition of the mother's blood or poisons circulating in the same, mechanical disturbances of the circulation, diseases of the genito-urinary organs, over-indulgence in sexual intercourse by the mother during pregancy, nervous causes, syphilis, streptococcal infections, etc. Abortion may also naturally be due to the disease of the membranes of the ovum or fœtus or diseases of the embryo itself.

(B) Artificial abortion

In certain cases the law permits the induction of premature labour and abortion if competent medical opinion decides that the life of the mother is in danger. This, however, is not resorted to unless all other means for preserving the life of the mother, and if possible that of the child also, have failed.

(C) Criminal abortion or fœticide

Criminal abortion is, for a variety of reasons, induced with the sole object of unlawfully destroying the impregnated ovum or the fœtus, and the law holds the attempt to do so equally guilty with the actual accomplishment. It has no moral, religious, social or legal sanction. Nevertheless, criminal abortion is undoubtedly prevalent in India as in other countries, although only relatively a small proportion of the cases are brought to light. Although no reliable statistics are available, it could perhaps be said with certainty that, on account of increase in population and the consequent ever-increasing struggle for existence together with a continued demand for higher standard of living, it is the married couples who are the most frequent perpetrators of this nefarious crime. Many a parent can ill-afford the educational and other expenses of a large number of children and simultaneously maintain the social position to which they belong. They feel the inconvenience of supporting a large family, and, without any compunction, conspire to get rid of their unborn baby. On the other hand, unmarried girls and widows, to get rid of the fruits of illicit intercourse and to hide the shame of their illegitimate pregnancy, also form a considerable percentage of these criminals.

Owing to the advent of various kinds of the so-called contraceptives it could be safely deduced that the necessity and frequency of resorting to abortion is on the decrease. These appliances for the prevention of fertilization of the ovum are, however, beyond the means of a vast majority of Indians, whose economic condition is very low. On the other hand, the use of the so-called infallible contraceptives by the married as well as the young, unmarried, inexperienced girls has not infrequently led to undesired pregnancy.

As soon as suspicion is aroused with regard to the condition of the female—after the omission of one menstrual period– the economic responsibilities in the case of married couples, the sense of shame and social abhorrence in the case of widows and unmarried girls, and loss of business in the case of prostitutes, become urgent considerations. The urge of getting rid of the ' unwanted arrival ' begins to get strong and the advice of confidential friends is sought. Usually some drugs are recommended which are tried at first. At many drug stores, medicines supposed to produce abortion are on sale, and many nostrums advertised to correct female irregularities are made, bought and used to procure abortion. Generally, however, they prove ineffectual ; and then active steps are taken to enlist the services of professional abortionists. These abortionists vary greatly in education

and technical skill. Some are well qualified for the purpose, while others, such as most of the *dais* or country midwives who mainly use drugs of vegetable origin or rash mechanical means, are quite ignorant of aseptic precautions and of the rudiments of anatomy. The patient sometimes learns from an abortionist a method of direct interference with the uterus, and, if this is successfull, she proceeds to apply it herself when another occasion arises. Often the woman does not realize the condition of her pregnancy till between the fourth and fifth months, when owing to the symptoms of quickening, she can no longer remain ignorant. At whatever time of gestation abortion is resorted to, it is attended with grave risk to the life of the unfortunate mother, unless it is performed by highly qualified gynæcologists. Since the services of expert gynæcologists are not easily available for the purpose of criminal abortion, the patient usually falls into the hands of quacks and often dies.

Criminal abortion endangers the mother's life by causing profuse hæmorrhage as a result of retention of the placenta or some other product of conception, or by septic inflammatory processes. In the case of abortion, which is procured through the agency of various instruments, perforation into the peritoneal cavity and septicæmia are the usual causes of death. It is interesting to note that more women die during attempt to procure criminal abortion than from childbirth and its complications. Peritonitis is the most common cause of death and is responsible for more than half the fatal cases. General septic infection kills about one-fourth. The remainder die from embolism, pneumonia or some other incidental infection [Davis, 1923]. Serious illness after criminal abortion is very common.

It is popularly believed that the earlier the period at which abortion is procured, the lesser is the danger to the life of the mother. This is not true. During the early gestation period the contractile powers of the muscles of the uterine walls are limited and hence the chances of hæmorrhage great owing to the non-occlusion of the bleeding vessels. At or near the completion of the term they are able to contract firmly and so occlude the bleeding vessels. Furthermore, if the uterus has not contracted thoroughly, the open sinuses are liable to absorb septic matter, so that septic infection is of much more frequent occurrence if the abortion occurs during the earlier periods of pregnancy than after delivery at the full term.

Methods of procuring abortion

The methods of procuring abortion are varied. Among these may be mentioned severe exercise, violent shaking of the body, tight lacing of the abdomen, and even trampling or kicking of the abdomen or other severe violent means. Mechanical means are also applied with a view to disturb the relation between the uterus and its contents, and are usually quite effective although usually accompanied with grave danger to the mother's life. For this purpose various kinds of instruments, such as wires, bones, twigs, etc. are used with the object of perforating the membrane surrounding the fœtus.

In India, quite a large number of *dais*, who practise the unlawful trade, introduce into the vagina or the *os* of the uterus sticks from six to eight inches long, which are commonly known as 'abortion sticks'. One end of these sticks is wrapped round with a piece of rag or cotton wool soaked with the juice of such plants as *madar* [*Calotropis procera* (Linn.) Dryand. and *C. gigantea* (Linn.) Dryand.], marking nut (*Semecarpus anacardium* Linn. *f.*), jequirity (*Abrus precatorius* Linn.), etc.; other ingredients of medication used for abortion sticks are arsenious oxide, orpiment and red lead. Some of the plants, the irritant twigs of which are similarly used, are *Plumbago indica* Linn. (*P. rosea* Linn.), *P. zeylanica* Linn., euphorbiaceous plants, and less frequently *Nerium indicum* Mill. (*N. odorum* Soland). These twigs are frequently smeared with asafœtida prior to introduction. The oral administration of reputed abortifacient drugs is, however, more frequently resorted to than any other method for procuring abortion.

Oral administration of abortifacient plants

It may be stated at the outset that administration of the so-called abortifacient drugs seldom answers the purpose for which they are used. When the desired object is attained, it is generally

from the use of a poisonous quantity, so that when the abortion is procured it is often followed by dangerous poisoning or death of the mother; not infrequently the mother dies without the production of abortion at all. It may be noted that all poisons, when taken in sufficiently large doses, may act as abortifacients, but such doses are generally attended with grave risks to the life of the mother.

Some of the plants used as abortifacients are supposed to produce uterine contractions which expel the contents of the gravid uterus; these are called ecbolics. Others, when used in the non-gravid condition, are supposed to promote menstrual flow or to re-establish it after its arrest from causes other than pregnancy; these are called emmenagogues. Still others have poisonous effects on the system generally.

The drug that enjoys the greatest reputation as an ecbolic is ergot, which is the sclerotium of the fungus *Claviceps purpurea* Tulasne, developed in the ovary of rye, *Secale cereale* Linn. It is a well-known medicine for exciting uterine contractions. It may be noted that while ergot is certainly capable of producing contractions of the uterus during the later stages of pregnancy, it is doubtful whether it can initiate uterine contractions in women during the early stages, or produce them with sufficient force so as to cause the expulsion of the fœtus. Some observers are of the opinion that ergot acts upon the uterus only when natural contractions of this organ have already begun; but, since uterine contractions normally occur during pregnancy it is conceivable that ergot may be able to augment the force of these contractions, although in the early months of pregnancy it may not be able to increase them sufficiently to procure abortion. Quinine from species of *Cinchona* is another drug which stimulates the contractions of the uterus when given in large doses; abortions have occasionally occurred after its use in malaria, while in other cases labour pains may be induced. Therapeutic doses, however, do not in most cases suffice to excite persisting activity in the quiescent gravid uterus, and are, therefore, not reliable for inducing premature labour, but if weak contractions are present, they are intensified. Like ergot it is conceivable that quinine may be able to augment the normal contractions of the uterus during pregnancy, but it may not be able to increase them sufficiently to procure abortion.

The emmenagogues, which often increase the menstrual flow in the non-gravid uterus, are very largely employed to induce abortion. They include all well-known drastic purgatives, such as aloes (*Aloe barbadensis* Mill.), and irritant volatile oils, such as pennyroyal (*Mentha pulegium* Linn.), savin (*Juniperus sabina* Linn.), tansy (*Tanacetum vulgare* Linn.). These are all intestinal irritants, and produce violent gastroenteritis (nausea, vomiting and diarrhœa). If the poison acts only when dissolved and is insoluble in the stomach, as is croton oil (from *Croton tiglium* Linn.), the nausea and vomiting may not be present, but only the diarrhœa. The hyperæmia produced is not confined to the intestines, but all the neighbouring abdominal organs partake of the congestion, although they do not come in direct contact with the irritant. It must be remembered that these emmenagogues produce their ecbolic effect only secondarily to the gastro-enteritis; the latter may be so violent as to be fatal without accomplishing the desired result. None of the intestinal irritants (drastic purgatives and irritant volatile oils) are suitable for procuring abortion and should never be employed as ecbolics. The volatile oils may, however, be useful as emmenagogues.

Besides the ecbolics and emmenagogues, some general poisons, such as Indian oleander (*Nerium indicum* Mill., syn. *N. odorum* Soland.), are also administered in India for procuring abortion. There does not appear to be any basis for their use, except that by acting as general poisons they may occasionally achieve abortion. There is always a grave risk to the life of the mother when these plants are employed.

A perusal of the above will show that there is no reliable plant or its product for procuring abortion, without endangering the mother's life. Despite this, the fact remains that ignorant persons do employ something or the other to achieve the object. Chopra and Badhwar [1940] have published a comprehensive list of Indian plants poisonous to man, livestock, insects and fishes. Their studies have revealed that a large number of plants are used in India for the purpose of procuring criminal abortion. In the present paper we deal with Indian plants which are applied locally on account of their irritant juices or are administered orally to procure abortion. A list of such plants, their important English and vernacular names, distribution, chemical constituents, properties and methods of use are discussed in the Appendix. Only plants indigenous to or cultivated in India are dealt

with. Plants or their products, like pennyroyal, savin, tansy, etc., although commonly used as emmenagogues or abortifacients in Western medicine and available at druggists' shops in India are excluded, since they do not grow in India. Further, such plants as croton, a drastic purgative found in India, will act like other drastic purgatives mentioned in the list, are also excluded, because they are not known to be used as abortifacients in this country.

The authors take the opportunity of expressing their grateful thanks to Col. Sir R. N. Chopra, C.I.E., for the help and guidance he has given in the preparation of this paper.

Appendix

Name of plant	Distribution	Constituents	Remarks
1. *Abrus precatorius* Linn. *English* : Crab's Eyes—the seeds, Indian Liquorice—the roots, Jequirity, Rosary Pea — the seed. *Vernacular* : *Gunchi, Gunja, Rattak, Ratti.*	Throughout the greater part of India, ascending the outer Himalayas to an altitude of 3,500 ft. ; sometimes planted in gardens.	Seeds contain the toxalbumin 'abrin' [Osborne, 1924], a crystalline nitrogenous compound abrine and an amorphous glucosidic substance abraline with a mild bitter taste [Ghatak and Kaul, 1932 ; Ghatak, 1934]. Leaves said to contain abrin and the leaves and roots glycyrrhizin [Wehmer, 1929-35].	Seeds ground into a paste and the mass made into sharp pointed needles used to procure criminal abortion ; for this purpose the juice of the plant also used as a local application. Powdered seeds when taken internally by women said to disturb the uterine functions and to prevent conception.
2. *Aloe barbadensis* Mill. (erroneously called *A. vera* Linn. in Indian literature). *English* : Socotrine or Zanzibar Aloe. *Vernacular* : *Mushabbar.*	Cultivated throughout India and even run wild as in the drier localities of South India.	Chief constituent aloin, which is glucosidic in nature, besides small quantities of an essential oil, a fixed oil, resin, gum, emodin, some anthraquinone derivatives and chrysophanic acid in some varieties [Chopra and Ghosh, 1938].	The use of the aloes or *mushab'ar* for causing purgation dates back to the 4th century B.C. The pronounced action of the drug on the large intestine induces some pelvic congestion and is therefore used as an emmenagogue. But it is contra-indicated during menstruation and must be used with caution during pregnancy and is likely to produce abortion. Indeed it has been frequently used in Europe for the purpose of procuring abortion.
3. *Ananas comosus* (Linn.) Merr. (*A. sativus* Schult. *f.*) *English* : Pine-apple plant. *Vernacular* : *Ananas, Anaras.*	Cultivated in various parts of India.	Fruit contains a digestive ferment, bromelin, which is more closely related to trypsin than to pepsin. Nothing is known regarding the presence of any poisonous chemical constituent [Wehmer, 1929-35].	Unripe fruit believed to possess emmenagogue properties. Also stated to be used to produce abortion in women as well as in animals. Even the juice of the ripe fruit held by some people to have irritant action on the uterus and to have the property of producing strong uterine contractions. The juice of leaves also stated to be used as an abortifacient [Watt, 1889-96].
4. *Annona squamosa* Linn. *English* : Custard Apple, Sweet-sop or Sugar Apple of the West Indies and America. *Vernacular* : *Ata, Sharifa, Sitaphal.*	Naturalized in several parts of India and is met with under cultivation and also as an escape.	Seeds yield an oil and a resin which contains the acrid principle [Watt, 1889-96]. Leaves and seeds found to contain an amorphous alkaloid but no glucoside [Trimurti, 1924].	When applied to *os-uteri* powdered seeds are irritant and said to produce abortion.
5. *Apium graveolens* Linn. *English* : Celery. *Vernacular* : *Ajmod, Bhutjata, Randhuni.*	Found at the foot of the North-West Himalayas and the outlying hills in the Punjab. Cultivated in different parts of India as a cold-weather crop.	A glucoside apiin [van Rijn, 1931] and an essential oil [Finnemore, 1926]. Apiole is the camphor obtainable from the essential oil of this plant.	Regarded as an emmenagogue, and is accredited with abortifacient properties.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
6. *Areca catechu* Linn. *English :* Areca Nut Palm, Areca Palm, Betel Nut Palm, Betel Palm, Catechu Palm, Supari Palm. *Vernacular : Supari.*	Extensively cultivated in moist tropical regions up to an altitude of 3,000 ft. Large scale cultivations in Southern and Western India, Assam, Bengal. Flourishes well in Malabar, Kanara and Mysore.	Nuts contain the alkaloid arecoline to the extent of about 0·1 per cent besides other alkaloids, such as guvacine, guvacoline, arecaidine and arecolidine [Henry, 1939].	'Malay women use the young green shoots as an abortifacient in early pregnancy.' [Kirtikar and Basu, 1933.]
7. *Aristolochia bracteata* Retz. *English :* Bracteated Birthwort. *Vernacular : Gandan, Kiramar.*	Grows on the banks of the Jumna and the Ganges, and in Bundelkhand, Sind and Konkan. In the Madras presidency it is found in the Northern Circars, the Deccan and Carnatic, on dry soils, especially the black cotton soil. Its occurrence in Bihar is doubtful.	Plant stated to contain a nauseous volatile substance and an alkaloid [Dymock, Warden and Hooper, 1890-93].	Plant accredited with emmenagogue and abortifacient properties and also used to increase the uterine contractions during labour.
8. *Aristolochia indica* Linn. *English :* Indian Birthwort, Sapsun. *Vernacular : Isharmul. Sapasan.*	Found throughout the low countryside of India from Nepal and the greater part of Bengal to Western and Southern India from Konkan southwards. Common in the jungles of South India among hedges and bushes.	Roots contain a phytosterol glucoside, an alkaloid aristolochine, a bitter substance isoaristolochic acid, and an essential oil containing a sesquiterpene ishwarene, a sesquiterpene ketone ishwarone, a sesquiterpene alcohol ishwarol, etc. [Krishnaswamy, Manjunath and Rao, 1935 : Rao, Manjunath and Menon, 1935].	Plant said to be used to procure abortion [Watt, 1889-96].
9. *Artemisia vulgaris* Linn. *English :* Flea-bane, Indian Wormwood, Motherwort, Mugwort. *Vernacular : Nagdona, Samri.*	A gregarious shrub found throughout the mountain tracts of India, especially between 5,000 and 12,000 ft. above sea level.	Essential oil containing α thujone, borneol, etc. [Finnemore, 1926].	In large doses it causes violent contractions of the uterus, labour-like pains, prolapse and rupture of the uterus, abortion, metorrhagia and increase in lochial discharges.
10. *Calotropis gigantea* (Linn.) Dryand. (*C. gigantea* R. Br.) *Vernacular : Ak, Akund, Madar.*	Frequently met with throughout India as a weed on fallow land and in waste ground except in the Punjab where its occurrence is doubtful.	Fibre contains a toxic bitter substance [Matthes and Streicher, 1913]. Milky juice found to contain a proteolytic enzyme similar to papain [Basu and Nath, 1933 ; *Ibid*, 1936]. Roots contain a guttapercha-like substance (*madar* alban) and a bitter yellow resinous substance [Sharma, 1934 ; Hill and Sarkar, 1915].	In India the juice of these plants used as an abortifacient, and for this purpose is either given internally or painted over the mouth of the womb, through the vagina, when it sets up intense irritation.
11. *Calotropis procera* (Linn.) Dryand. (C. procera R. Br.) *Vernacular : Ak, Akund, Madar.*	Found more or less throughout India in warm and dry places from the North-West Frontier Province and the Punjab to Western, Central and Southern India. Occurs abundantly in Sub-Himalayan tracts and the adjacent plains in the North-West.	Milky juice contains a proteolytic enzyme and a toxic substance [Gerber and Flourens, 1913]. Also contains a highly active resin [Gerber and Flourens, 1912]. Root bark contains a bitter yellow-resin but no alkaloid [Sharma, 1934].	See under *C. gigantea* (Linn.) Dryand.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
12. *Carica papaya* Linn. *English* : Melon Tree, Papaw, Papaya, Papeta, Paupau, Pawpaw, Tree Melon. *Vernacular* : *Arand-kharbuza, Papaya, Papita.*	Extensively cultivated throughout India. Does not grow well in the drier parts of India but thrives well where rainfall is high and climate hot.	Latex or the milky juice contains a proteolytic enzyme papain and also a milk-curdling ferment. Leaves contain a glucoside carposide and an alkaloid carpaine [van Rijn, 1897]. Milky juice, bark, roots and seeds contain only traces of carpaine [Greshoff 1890 ; van Rijn, 1893].	A belief in the powerful emmenagogue properties of the seeds prevails among all classes of people in Southern India, who assert that if a pregnant woman partakes of them even in moderate quantities, abortion will result.
13. *Celastrus paniculatus* Willd. *English* : Black-oil plant. *Vernacular* : *Malkangani, Valuluvai.*	Found in tropical and sub-tropical Himalayas, the Punjab and throughout the hilly districts of India ascending to 4,000 ft. above sea level.	Seeds yield on expression a fatty oil (Celastar oil) and by destructive distillation an empyreumatic oil [Wehmer, 1929-31].	Seeds said to be used to procure abortion though nothing known regarding their abortifacient properties.
14. *Cinchona calisaya* Wedd. *English* : Bolivian Bark, Calisaya Bark, Yellow Bark. *Vernacular* : *Burak, Shurappattai.*	Cultivated in Sikkim and Nilgiris.	A number of alkaloids obtained from the bark of which the best known are quinine, quinidine, cinchonine, cinchonidine, besides a few free organic acids, tannins, some neutral substances, colouring matters, traces of volatile oils, gum, starch and other vegetable matters.	Unstriated muscle in the mammals tends to contract under the influence of quinine, the action being especially marked on the uterus which is thrown into rhythmical contraction. Abortion occurs occasionallly after its use in malaria, while in other cases labour pains may be induced.
15. *Cinnamomum camphora* Nees & Eberm. *English* : Camphor laurel, Camphor Tree. *Vernacular* : *Kapur, Kappur, Kappuram.*	Indigenous to Formosa, China and Japan ; planted in some gardens up to an altitude of 4,000 ft. in the North-West Himalayas.	Leaves, stems and fruits contain an essential oil (Camphor oil) with 50-55 per cent of camphor [Wehmer, 1929-35].	In India camphor is often administered along with plantains to produce abortion ; about 20 grains are believed to be sufficient for the purpose [Watt., 1889-96].
16. *Citrullus colocynthis* Schrad. *English* : Bitter Apple, Bitter Cucumber, Colocynth, Coloquintide. *Vernacular* : *Indrayan, Makal, Tumma.*	Found wild in waste lands throughout India, particularly in the North-West, Central and South India.	Fruit pulp of colocynth contains traces of an essential oil, a dihydric alcohol designated as citrullol, a weekly basic alkaloidal principle, and some resinous material. Amount of glucosidic substance contained in the fruit is extremely small [Wehmer, 1929-35].	Taylor cites the case of an adult female who took 120 grains of the powder in order to produce abortion, and died in fifty hours. [Waddell, 1928].
17. *Crocus sativus* Linn. *English* : Saffron. *Vernacular* : *Jafran, Kesar, Zafran.*	Cultivated at an altitude of 5,000 to 6,000 ft. in Pampur, Kashmir.	Saffron contains a glucoside, a bitter substance and an essential oil [Wehmer, 1929-35]. Bulbs contain a saponin [Watt and Breyer-Barndwijk, 1932].	Stated to have been used as an abortifacient, but apparently lacks this action and is practically non-toxic [Sollmann, 1936].
18. *Cucumis trigonus* Roxb. *Vernacular* : *Bislambhi, Gomuk, Jangli-indrayan, Karit.*	Found throughout the greater part of India.	Fruit contains colocynthin or a substance of a similar nature [Naylor and Chappel, 1907].	Bitter pulp used as substitute for colocynth and is a drastic purgative. Waddell [1928] mentions a case which was reported to the Bombay Chemical Analyses' office in 1833 in which it was stated that the root of this plant had been administered for the purpose of procuring abortion.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
19. *Cuscuta reflexa* Roxb. *English :* Dodder. *Vernacular : Akash bel, Amarvel, Imalbel, Kashus, Zarbuti.*	Occurs as a parasite throughout the plains of India ascending up to 8,000 ft. above sea level ; often very destructive to small trees and shrubs if left to itself.	Plant found to contain the colouring matter cuscutin [Agarwal and Dutta, 1935] but nothing of pharmacological importance isolated.	The *dais* (Country midwives) in the Punjab have a great faith in a decoction of this plant as an abortifacient. A decoction made in boiling water from 180 grains of this plant is said to produce depression with nausea and vomiting, followed by abortion [Dulip Singh, 1885].
20. *Daucus carota* Linn. *English :* Carrot. *Vernacular : Gajar.*	Cultivated throughout India as an article of food.	Fruit of the cultivated carrot yields 1 to 1·5 per cent of an essential oil, and a crystalline body named daucol [Finnemore, 1926].	Seeds popularly regarded as a powerful abortifacient, and numerous cases of abortion, following their internal administration, are on record. More precise information is, however, wanted with regard to their alleged abortifacient properties.
21. *Dolichandrone falcata* Seem. *Vernacular : Bhersing, Kanseri, Mendel.*	Found in Rajputana, Bundelkhand, Bihar, Central Provinces, Berar, Konkan, Deccan, Mysore and most districts of the Madras Presidency in dry deciduous forests and often on rocky slopes.	....	Plant reputed to be an abortifacient though its specific abortifacient power not known.
22. *Euphorbia tirucalli* Linn. *English :* Milk bush, Milk hedge, Indian Tree Spurge. *Vernacular : Lanke-sij, Nevli, Sehund, Shir-thor.*	A native of Africa but become naturalized in many places in India. Often grown as a hedge or occasionally as a roadside tree.	Milky juice contains about 20 per cent of resins [Wehmer, 1929-35].	Twigs of this plant are stated to be inserted into the vagina or uterus for procuring abortion.
23. *Excoecaria agallocha* Linn. *English :* Blinding Tree. *Vernacular : Gaucwa, Geon, Haro.*	Found in tidal forests and swamps on all the coasts of India.	....	Dr C. R. Dutt, Asstt. Surgeon, Patuakhali, Bengal, reported to the authors a case wherein the fresh juice of the plant was given to a pregnant woman carrying five months with a view to procure abortion, with successful results.
24. *Garcinia morella* Desr. *English :* Gamboge Tree. *Vernacular : Devanahuli, Jarige, Pesupuvarna, Tamal.*	An evergreen tree found in the forests of Eastern Bengal, the Khasia Mountains and the Western Ghats from Kanara and Mysore to Travancore.	Gamboge contains 70-80 per cent of resin, 15-20 per cent of gums and a small quantity of vegetable debris. Resin consists of several resinic acids named as 'garcinolic acid', also esters and neutral resene [Allen, 1923-33]. These acids form readily soluble compounds with alkalis and thus become active in the intestine. Effects resemble those of colocynth.	Gum-resin used as an abortifacinet. In doses of one to five grains it has a purgative action, but cases are on record where large doses, such as of one drachm have resulted in death.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
25. *Gossypium herbaceum* Linn. *English :* Cotton Plant. *Vernacular : Kapas, Rui.*	Cultivated throughout the hotter regions of India.	Root-bark contains a pale yellow or colourless acid resin to the extent of about 8 per cent [British Pharmaceutical Codex, 1934], and also gossypol [Sollmann, 1936].	Attention appears to have been first drawn to the emmenagogue property of the root-bark from the observation of Dr Bouchelle of Mississipi who stated that it was used by negro women to procure abortion. There appears to be little doubt that it acts like ergot upon the uterus, and is useful in dysmenorrhoea and suppression of the menses when produced by cold [Watt, 1889-96].
26. *Gloriosa superba* Linn. *English :* Glory Lily. *Vernacular : Agnisikhe, Bachnag, Bisha, Dudhiovachnag, Garbhaghatini Kalihari, Kathari, Kulhari.*	Found throughout India ascending up to an altitude of 7,000 ft. on the hills. Common in Mysore State.	Roots contain a bitter principle [Warden, 1880]. Tubers contain an enzyme, an alkaloid colchicine and two other crystalline bases. Toxic properties of the tubers due essentially to the colchicine present.	It constitutes one of the seven minor poisons of Sanskrit writers. Its Sanskrit synonym 'garbhaghatini' means 'the drug that causes abortion'. The tuberous roots are indeed, popularly believed in India to be highly poisonous and are used to some extent at least to commit suicide and procure abortion [Watt, 1889-96].
27. *Lepidium sativum* Linn. *English :* Cress. *Vernacular : Halim.*	Cultivated throughout India	Seeds contain an essential oil [Finnemore, 1926].	Seeds used in indigenous medicine. Over doses believed to produce abortion.
28. *Momordica charantia* Linn. *English :* Carilla Fruit. *Vernacular : Karela.*	Largely cultivated throughout India for its young fruits, of which there are several cultivated forms, differing in shape and size.	Leaves contain a bitter substance 'momordicin' 'resins', two resin acids, etc. [Wehmer, 1929-35]. Plant contains about 0·038 per cent of an alkaloid [Luis Torres Diaz, 1936] and the seeds yield about 32 per cent of a purgative oil [Freise, 1929].	In India, the roots stated to be used successfully for procuring abortion [Waddel, 1928]. A case wherein abortion was produced at the seventh month by swallowing a decoction of the roots of this plant has been reported [Bomb. Chem. Analyser's Rep., 1879-80].
29. *Momordica tuberosa* Cogn. (*M. cymbalaria* Fenzl *ex* Naud.) *Vernacular : Kadavanchi.*	Found in the western parts of India from Sattara district in the north down to Tinnevelly in the South.	Tubers said to contain a bitter glucoside [Dymock, Warden and Hooper, 1890-93].	Whole plant acrid and the ovoid tuberous roots reported to have been used in procuring abortion, a decoction being administered for this purpose [Watt, 1889-96].
30. *Moringa oleifera* Lam. (*M. pterygosperma* Gærtn.) *English :* Drum-stick Tree, Horse-radish Tree. *Vernacular : Guggala, Karunjanam, Mangai, Murunga, Segata, Suhajana.*	Grows wild in the Sub-Himalayan tract from the Chenab to Oudh, and is commonly cultivated throughout India.	The root bark contains 0·105 per cent of alkaloids, an essential oil with a very pungent smell, a crystalline base termed moringine which is physiologically inert, and a liquid base, moringinine, which is physiologically active. [Ghosh, Chopra and Dutt, 1935].	Gum said to procure abortion but reliable information on this point lacking. It may be possible to use it as a tent to dilate the *os uteri*, as it is tough and swells rapidly when it draws moisture [Watt, 1889-96].

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
31. *Nerium indicum* Mill. (*N. odorum* Soland.) *English :* Indian olaender, Sweet-scented Olaender. *Vernacular :* *Ganira, Kaner, Khar-zahrah, Sum-el-himar.*	Found in the Himalayas from Kashmir to Nepal up to an altitude of 6,500 ft, on the Punjab Salt Range extending westerds to Baluchistan, and also in Central India. Cultivated throughout India in gardens and is apparently wild in South India and in the Bombay Presidency along banks of streams.	Roots, bark and seeds contain the toxic principles neriodorin, neriodorein and karabin. [van Rijn, 1931 ; Bose, 1901].	Several suicidal, homicidal and abortion cases are on record in India from the use of this plant. Commonly used for procuring criminal abortion both by local application and internal administration. In fact the poisonous properties are so well known in India that it is a proverbial taunt among females to say 'Go and eat the *kaner* root'.
32. *Nigella sativa* Linn. *English :* Small Fennel, Black Cummin. *Vernacular :* *Kala - jira, Kalonji, Mugrela.*	Cultivated extensively in many parts of India for its seeds.	Seeds stated to contain 0·5 to 1·4 per cent of an essential oil and a saponin-like glucoside, melanthin [Wehmer, 1929-35].	Seeds used as emmenagogues in Europe ; in doses of 10 to 20 grains they possess a well-marked emmenagogue action in dysmenorrhœa, and in larger doses produce abortion [Watt, 1889-96].
33. *Peganum harmala* Linn. *English :* Harmal, Syrian Rue, Wild Rue. *Vernacular :* *Harmal, Kaladana, Spalanai, Spanda.*	Very common in the drier waste places and fields of Baluchistan, Waziristan, Kurrum Valley, Sind, Cutch, the Punjab, Kashmir, Delhi, the United Provinces, Bihar, Konkan and the Western Deccan.	Seeds found to contain three alkaloids — harmine, harmaline and harmalol to the extent of 2·5 to 3 per cent. Recently another alkaloid, peganine, isolated from the seeds which is stated to be identical with vasicine, the alkaloid found in *Adhatoda vasica* Nees. [Henry, 1939]. They also contain a soft resin with deep carmine-like colour having a heavy narcotic odour resembling that of the resin of *Cannabis sativa* Linn. [Watt, 1889-96].	Seeds considered narcotic nauseant, emetic and emmenagogue. Gopal, as quoted by Watt [1889-96] found that an infusion or tincture acted as a mild emmenagogue. He reported that the plant was sometimes employed by Indian midwives to procure abortion and believed that the drug has properties similar to those of ergot, savine and rue.
34. *Plumbago indica* Linn. (*P. rosea Linn.*). *English :* Fire Plant, Officinal Leadwort, Rosy-flowered Leadwort. *Vernacular :* *Chitra, Chittermul, Lal-chita, Lal-chitarak.*	Largely cultivated in gardens and stated to occur in a state of nature in the Bengal Duars, Sikkim and Khasia. Also found as an escape in Southern India.	Root-bark contains the toxic substance plumbagin but no alkaloid [Katti and Patwardhan, 1932].	Root mentioned by ancient Sanskrit and Mohammadan writers as an abortifacient and vesicant. It is commonly used in India for producing abortion. With this object it is sometimes given internally and has more than once been detected as plumbagin in pills stated to have been administered for this purpose. Usually, however, it is employed as a local irritant application to the *os-uteri*, a portion of the scraped root or twig of the plant being pushed into the vagina, and sometimes even into the uterus. In other cases the end of an abortion stick is covered with a paste made from the powdered roots. Death not infrequently results from the introduction of this highly acrid agent if used in any of the above ways.

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
35. *Plumbago zeylanica* Linn. *English :* White-flowered Leadwort. *Vernacular :* *Chitra, Chitramula, Safed-chita, Safed-chitarak.*	Largely cultivated in gardens throughout India and often seen as an escape. Grows wild in south India and probably also in Bengal.	Roots contain plumbagin which is absent in the leaves and stems [Roy and Dutt, 1928].	Possesses properties similar to those of *P. indica* Linn. and both used for the same purposes.
36. *Plumeria acuminata* Ait. (*P. acutifolia* Poir.). *English :* Frangipani, Jasmin Tree, Pagoda Tree. *Vernacular :* *Arali, Champa, Gobur-champ, Golainchi, Gosampige, Gulchiu.*	Cultivated as an ornamental tree throughout India and became naturalized in many places.	Bark contains a bitter glucoside named plumierid which changes to plumieric acid after treatment with alkaline solutions even in cold [van Rijn, 1931]. Milky juice contains plumeric acid, as a calcium salt [Wehmer, 1929-35].	Root a violent cathartic and blunt-ended branches used to procure abortion [Watt, 1889-96].
37. *Randia dumetorum* Lam. *Vernacular :* *Ghela, Maindal, Menphal, Rara.*	Found in the Sub-Himalayan tract from Rawalpindi district up to 4,000 ft. Extends southwards to Chittagong.	Fruits contain a saponin in the pericarp, a glucosidic saponin in the pulp and seeds traces of an alkaloid [Vogtherr, 1894]. An essential oil also present [Chopra, 1933].	Pulp of the fruit said to be used sometimes as an abortifacient [Watt, 1889-96].
38. *Rubus moluccanus* Linn. *Vernacular :* *Katsol, Sufokji.*	Common in many parts of central and eastern tropical and temperate Himalayas from Kumaon to Sikkim at altitudes of 3,000 ft. to 7,000 ft. Occurs also in Assam and in the Khasia Hills at altitudes of 3,000 to 5,000 ft. above sea level, and in the Ghats from Bombay southwards.		According to Rumphius the leaves are abortifacient and a powerful emmenagogue [Watt, 1889-96].
39. *Ruta graveolens* Linn., var. *angustifolia* Hook. *f.* *English :* Ave Grace, Common Rue, Countryman's Treacle, Garden Rue, Herb of Grace, Herb-repentance, Herb of repentance. *Vernacular :* *Pismarum, Sadab, Satapa, Satari, Sudah.*	Cultivated in Indian gardens for the medicinal properties of its leaves and seeds.	A volatile oil (oil of rue) obtained to the extent of about 0·06 per cent by distilling the fresh herb in water. A glucoside rutin and a coumarin-like odoriferous principle also isolated from the plant [Watt and Breyer-Brandwijk, 1932].	Oil from *Ruta graveolens* Linn. used for several purposes in western medicine. Given internally it acts as an emmenagogue in doses of 2 to 5 drops. In larger doses, however, it acts as an abortifacient and produces irritant symptoms. Indian variety appears to be a perfect substitute and finds similar uses in indigenous medicine. The oil and the herb frequently employed to produce criminal abortion both in Europe and India though in ordinary doses it appears to have no effect on the uterus.
40. *Salicornia brachiata* Roxb. *Vernacular :* *Mechul, Kattumari, Umari.*	Found in Gujerat, Kathiawar, Western and Eastern Coast of the Madras Presidency, Sundarbans, etc., on saline marshes or ground covered by the tides.		Ash considered to have emmenagogue and abortifacient properties [Kirtikar and Basu, 1933].

APPENDIX—*contd.*

Name of plant	Distribution	Constituents	Remarks
41. *Sapindus trifoliatus* Linn. *English :* Soap Nut Tree of South India. *Vernacular :* *Antala, Arishta, Kottaimaram, Ritha.*	A common tree about the villages in South and West India; also cultivated in Bengal and planted elsewhere also.	Pericarp contains a fairly large quantity of saponins, about 4-5 per cent [Wehmer, 1929-35].	Nut stated to be used for procuring abortion.
42. *Semecarpus anacardium* Linn. *f.* *English :* Marking-nut tree. *Vernacular : Bhela, Bhilaran, Bhilawa.*	Found in the Sub-Himalayan tract from Bias eastwards, ascending in the outer hills up to 3,500 ft. Assam, Khasia Hills, Chittagong, Central India, Gujerat, Konkan, Southern Mahratta Country, Kanara and in deciduous forests of all districts in the Madras Presidency.	Juice of the pericarp contains (*a*) semecarpol, (*b*) bhilawanol, and (*c*) a tarry, non-volatile corrosive residue forming about 18 per cent of the nut [Pillay and Siddiqui, 1931].	Externally a powerful counter-irritant and vesicant. Applied locally for procuring criminal abortion.
43. *Sesamum orientale* Linn. (*S. indicum Linn.*). *English :* Gingelly-oil Plant, Sesame. *Vernacular : Gingli, Kala-til, Krishna-til, Til.*	Largely cultivated throughout India, being grown as an autumn or even as a winter crop in the warmer parts of the country (the truly tropical areas), and as a summer one in the colder areas.	Oil from the seeds contains about 1 per cent of *sesamin* and *sesamolin*. The latter breaks up into a phenolic substance sesamol and another substance samin [Andriani, 1928].	Kobert [1906] states that the seeds have been used since olden times as emmenagogue and abortive, an opinion which has also been expressed by some writers in India. This view, however, seems to be incorrect, judging from the extent to which it is often eaten by Indian women, as for example during the 'bhugga' festival of the Hindus in the Punjab. The existence of any such belief among Indian ladies is unknown.
44. *Stachytarpheta jamaicensis* (Linn.), Vahl. var. *indica* H. J. Lam (*S. indica* Vahl). *English :* Aarons Rod. *Vernacular :* *Jalagali, Kariyu Harni, Sinainairirunji.*	Found practically throughout India from the Punjab and Sylhet to Travancore. Common as a weed. Sometimes grown in gardens.	Said to contain a glucosidic substance [Wehmer, 1929-35].	Not put to any use in India but stated by Pammel [1911] to have abortifacient properties.
45. *Taxus baccata* Linn. *English :* Yew. *Vernacular : Barini, Birini, Postal, Thuna.*	Met with in temperate Himalayas at altitudes of 6,000 ft. to 11,000 ft., and in the Khasia Hills at altitudes of 5,000 ft.	Leaves, shoots, and 'fruits' contain a toxic alkaloid taxine [Henry, 1939]. Sap acrid and contains a volatile oil [Lander, 1926]. Leaves contain much formic acid [Blyth, 1920] and also the glucoside taxicatin [Lefebvre, 1907] and small amounts of ephedrine [Gutland and Virden, 1931].	Leaves occasionally employed by ignorant people to procure abortion. [Watt, 1889-96].
46. *Thevetia peruviana* (Pers.) Merr. (*T. nereifolia* Juss. *ex* Steud.). *English :* Bastard Oleander. Exile Oleander. Yellow Oleander. *Vernacular : Chinakurab Kolkephul, Pila-kaner, Zard-kaner.*	Originally a native of America and West Indies, now almost naturalized in some places. Scarcely a garden in the plains without a few shrubs, if not a hedge.	A fatty oil constituting more than 62 per cent of the kernel and four crystalline substances—phytosterolin, ahouain, kokilphin and thevetin [Chen and Chen, 1934]. Roots also found to contain thevetin [Arnold Middleton and Chen, 1935].	Seeds long known to be highly poisonous and commonly used by women as an abortifacient, especially in Bengal and neighbouring provinces.

APPENDIX—*concld.*

Name of plant	Distribution	Constituents	Remarks
47. *Trianthema pentandra* Linn. *Vernacular : Bishkapra, Itsit.*	A common weed growing on waste lands in the plains of the Punjab, Sind and North-West India.		Plant believed to cause abortion and apt to produce diarrhœa and paralysis [Stewart, 1869].
48. *Trianthema portulacastrum* Linn. (*T. monogyna* Linn.). *English :* Horse Purslane. *Vernacular : Bishkapra, Itsit, Sabuni, Swetpunarnava.*	Common throughout India .	The authors have found the presence of water soluble bases and potassium salts in the plant.	Roots stated to have cathartic and irritant properties and used to procure abortion. [Dymock, Warden and Hooper, 1890-93].
49. *Urena lobata* Linn. . *Vernacular : Bachita, Ban-ochra, Vana-bhenda.*	A common herb, generally distributed throughout the hotter parts of India, very frequently in waste places, and in the bamboo and mango clumps of Bengal.	Seeds contain an enzyme, urease [Wehmer, 1929-31].	A private communication from Dr R. C. Muirhead Thomson of the Tocklai Experimental Station, Cinnamara, Upper Assam to the authors states that root of this plant are supposed to be widely used for procuring abortion. A short piece of the root is inserted into the vagina and left there for several hours. Said to be widely used by the Assamese and may possibly be used by the tea garden coolies too.
50. *Withania somnifera* Dun. *Vernacular : Asgand, Asvaganda.*	Found throughout the drier parts of India, especially in waste places, ascending to 5,000 ft. on the Himalayas.	Root contains 0·006 per cent of a light brown and pungent volatile oil and an amorphous alkaloidal principle. Leaf and stem yielded traces of volatile oil, tannin, a considerable amount of potassium nitrate, etc. [Power and Salway, 1911]. Besides the above alkaloid three other bases isolated from the resin obtained from the plant [Majumdar and Guha, 1933].	Root occasionally employed in the Punjab to effect criminal abortion, and the same practice believed to be common in Sind [Stewart, 1869]. Pammel [1911] also states that the plant has abortifacient properties.

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THE EFFECT OF CERTAIN SOIL FACTORS ON THE YIELD OF MAJOR CROPS IN THE PUNJAB

II. RICE

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(Received for publication on 15 October 1945)

(With 17 text-figures)

Although several attempts had been made in the past to work out statistical correlations between the yield of agricultural crops with certain meteorological factors, little attention had been paid to correlate the yield with main characteristics of soils bearing those crops. The authors in a previous publication [1941] presented the analyses of soils taken from wheat areas in the various districts of the Punjab and their statistical relationships with the figures for the yield of wheat. That previous work brought out significant correlations between the manganese and available phosphate contents of those soils and the yield of wheat and was of sufficient interest to justify the extension of work on those lines to soils representing other major agricultural crops of the Province. The present study relates to the effect of certain soil characteristics on the yield of rice.

Collection of soil samples

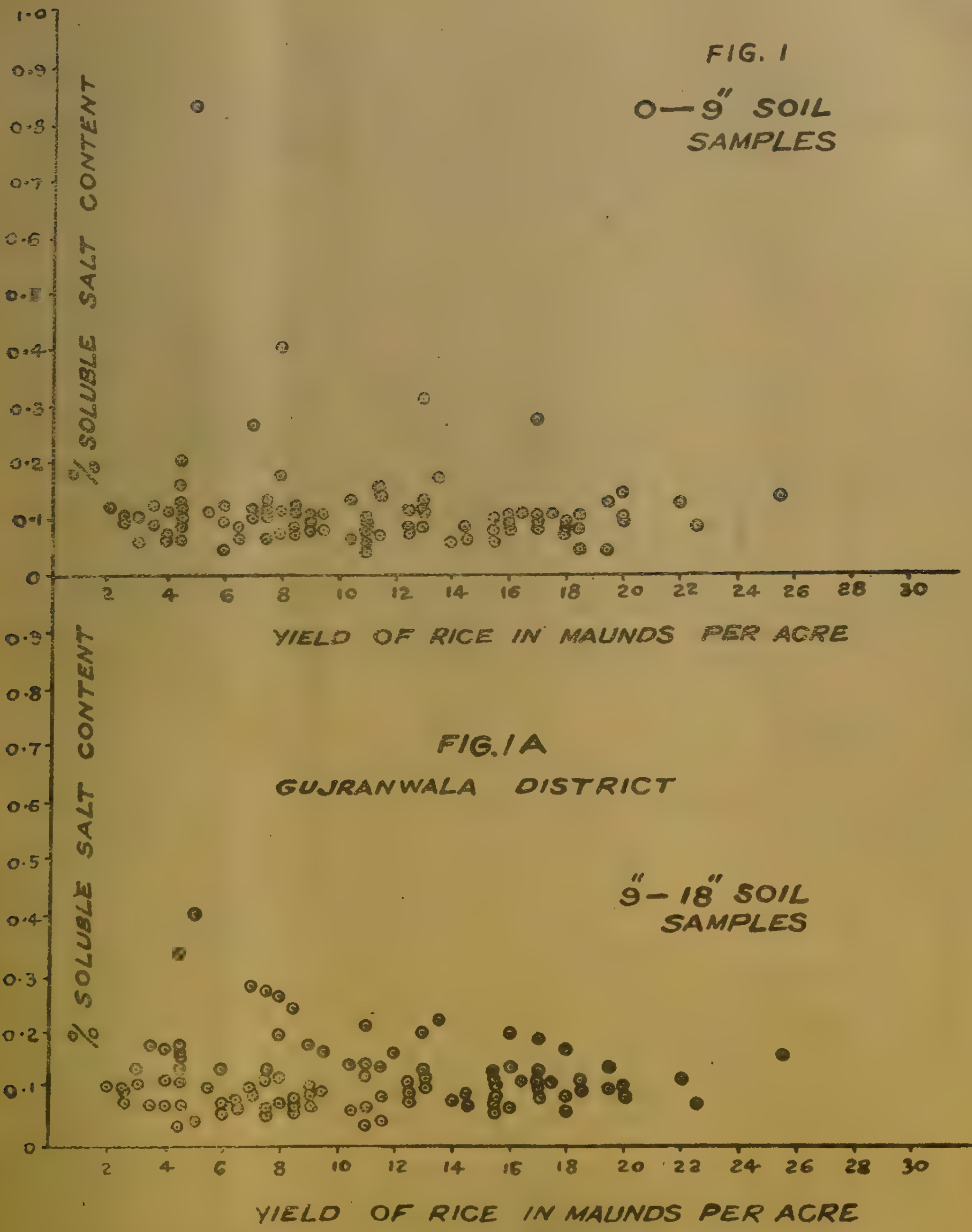
For the present investigation soil samples were taken from a large number of fields in the two predominantly rice growing districts of the Province, viz. Gujranwala and Sheikhupura. The sampling was restricted to the top 18 inches soil at each site. The soil profile was exposed to that depth near the centre of each field to be sampled and two samples collected, one from top nine inches representing the depth mainly affected during ploughing and the other from the next nine inches which usually contains the major part of the root system of the crop. Thd yields of rice, expressed in maunds (equivalent to 82 lb.) per acre, of all fields sampled were ascertained with the help of canal *patwaris* and local zemindars. As far as possible, the fields selected for this study were normal from the point of view of irrigation applied, crop rotation, etc., so that the difference in the crop yields could be attributed mainly to differences in certain characteristics of soils of those sites.

Experimental

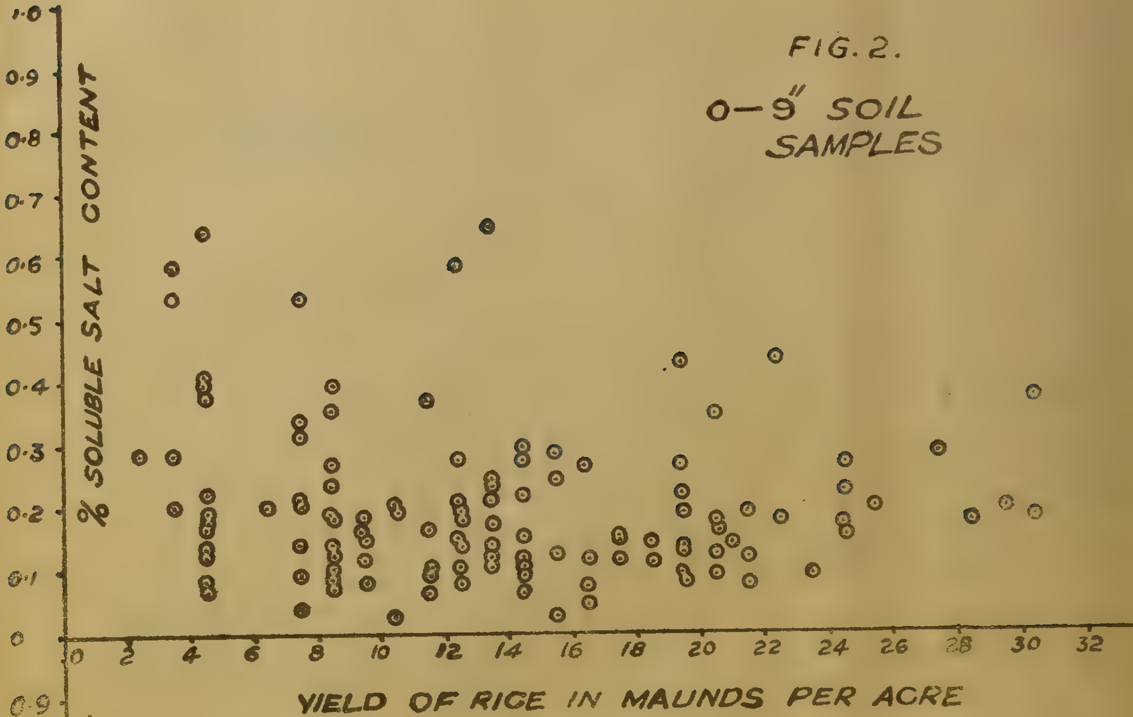
The following is a brief description of the technique adopted for the analysis of the soil samples :

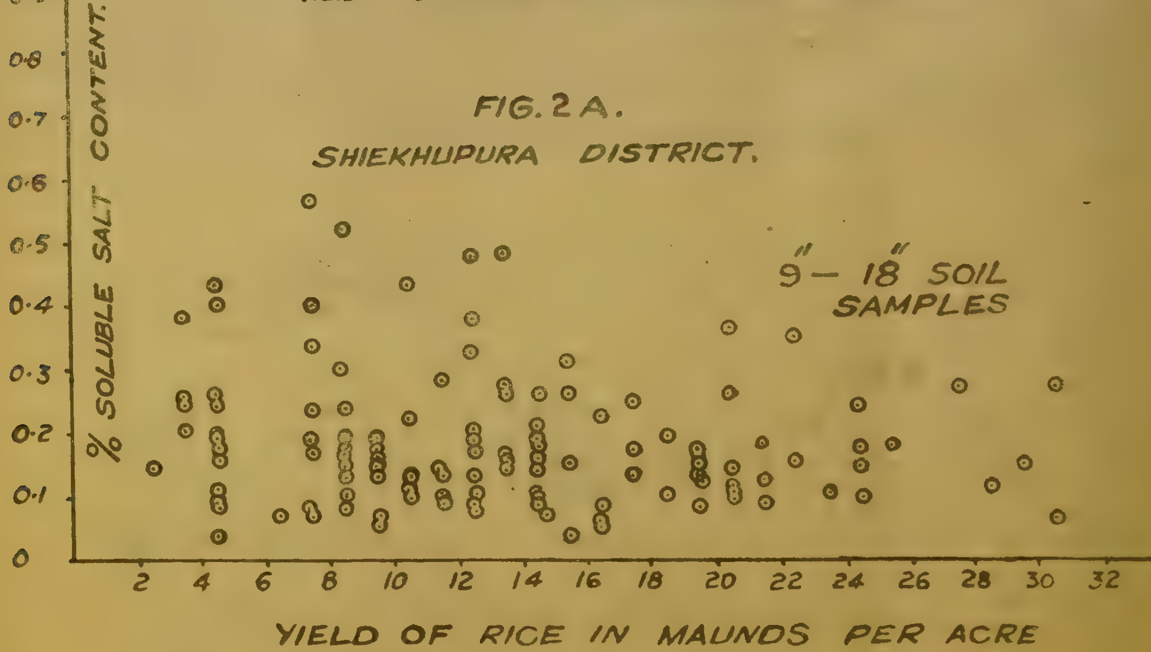
The soluble salt content was determined by evaporating an aliquot of water extracts prepared from 1 : 5 soil-water suspensions. The pH of 1 : 5 soil-water suspensions were determined with glass electrode [Hoon and Taylor, 1931]. The total manganese content was determined by the bismuthate method as recommended by the Bureau of Soil Science [1937]. The available phosphates were extracted from soils with carbon dioxide [Puri and Asghar, 1936] colour developed according to Chapman [1932] and matched against colour standards employing Bolton and Williams' photoelectric colorimeter. Boron was extracted from soils with hot water, quinalizarin employed for developing colour [Smith, 1935] and estimated colorimetrically. Total nitrogen was determined by Kjeldahl's method as modified by Bal [1925]. The calcium carbonate content was determined by titration with sulphuric acid [Puri, 1930]. . The exchangeable bases were determined by the usual methods. The degree of alkalization was calculated from the contents of the main exchangeable bases [Puri, 1933].

The results of the various analyses have been represented diagramatically against the yield of rice in maunds separately for the top nine inches (Figs. 1-16) and the second nine inches soil samples (Figs. 1A-16A) of the two districts.

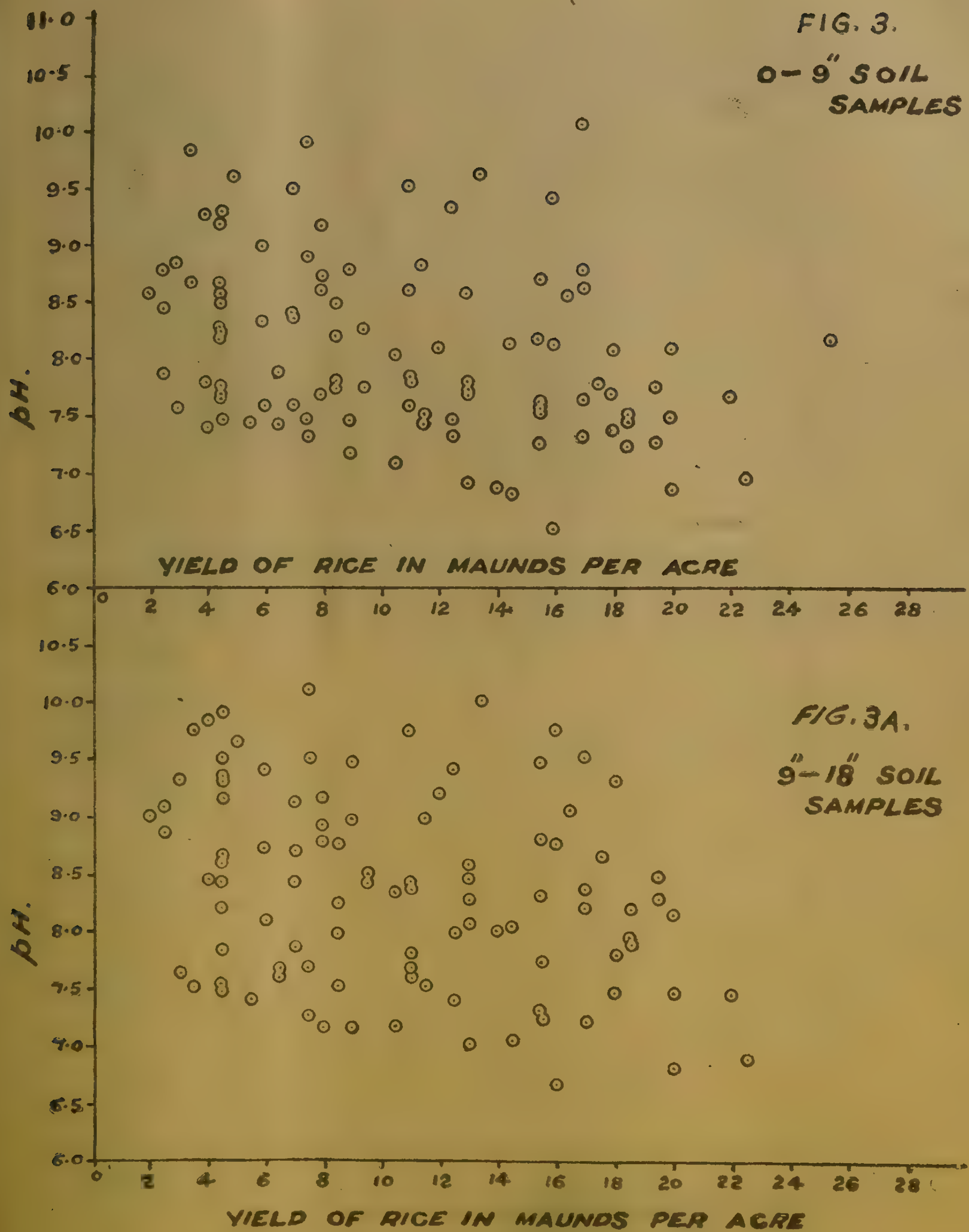


FIGS. 1 and 1A. Soluble salt content of soils of Gujranwala district in relation to the yield of rice

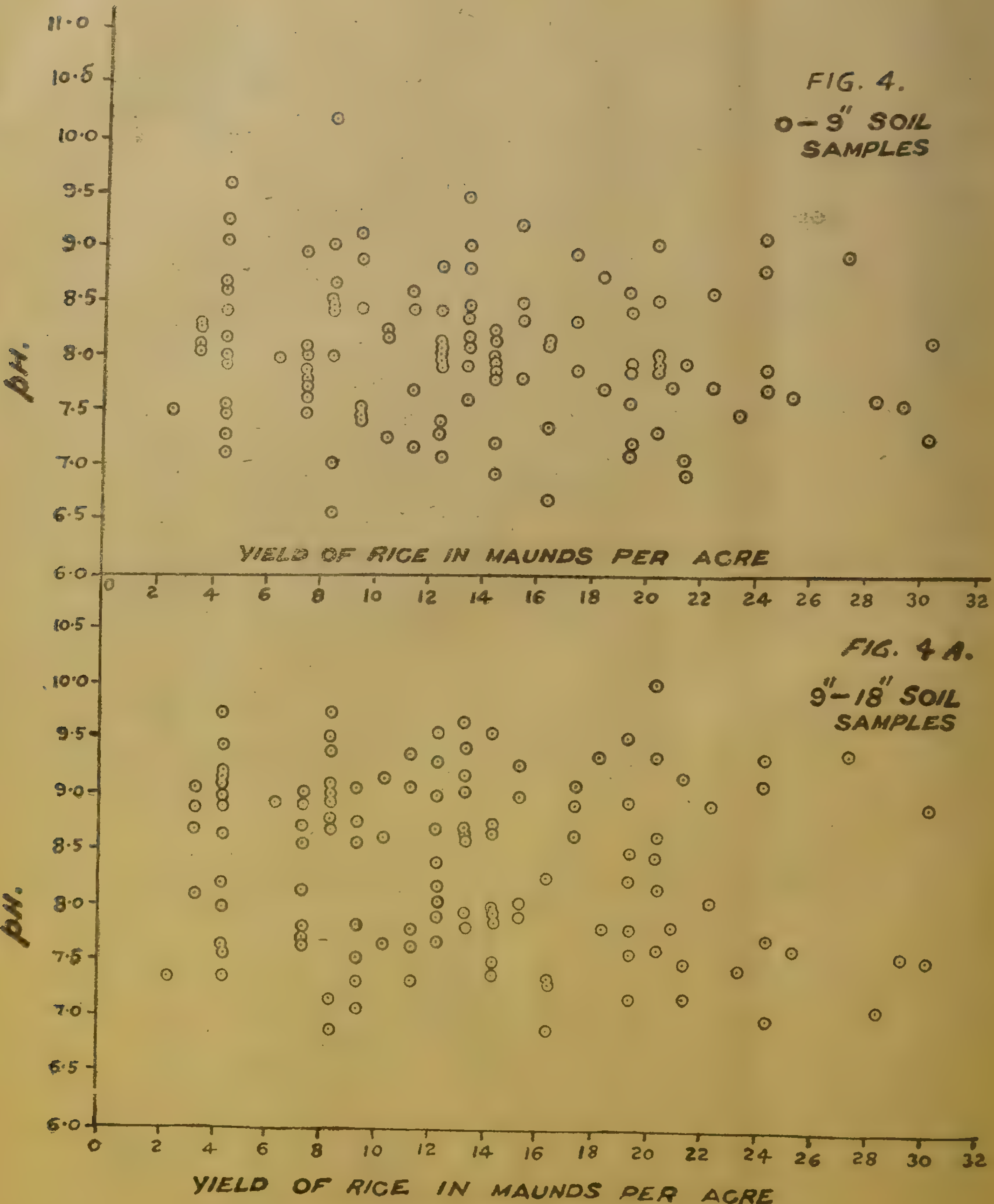




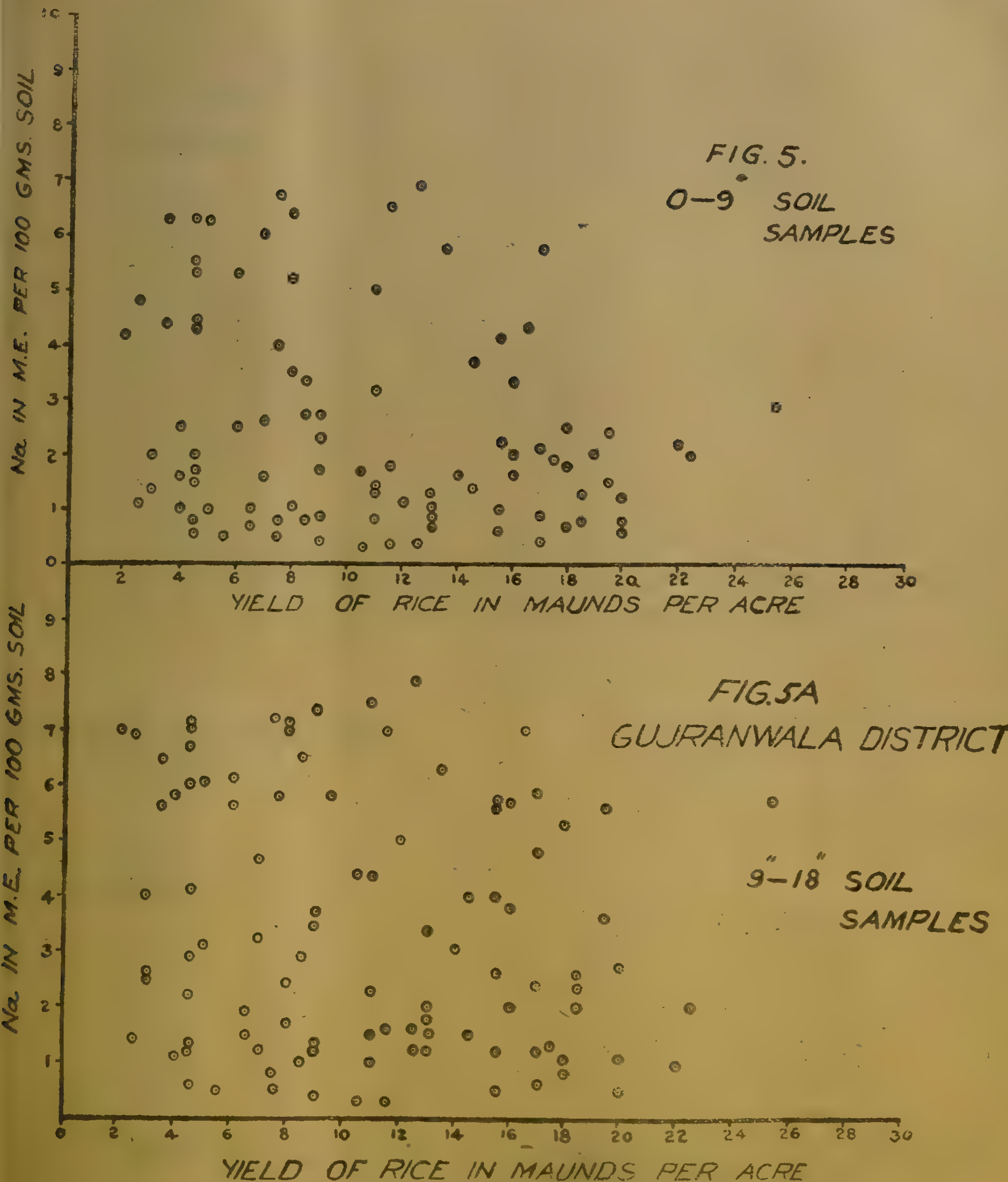
FIGS. 2 and 2A. Soluble salt content of soils of Sheikhupura district in relation to the yield of rice



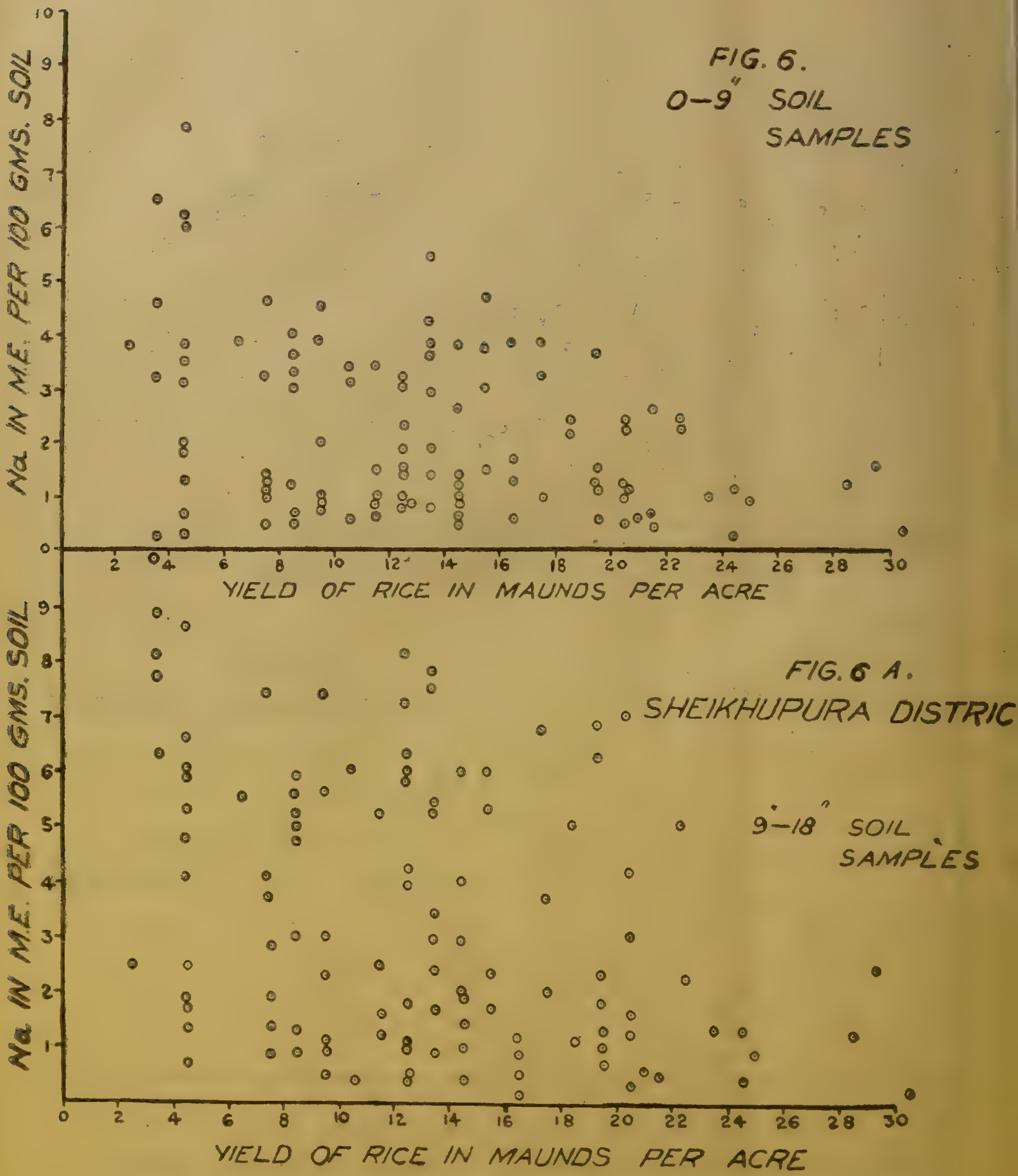
Figs. 3 and 3A. pH of soils of Gujranwala district in relation to the yield of rice



FIGS. 4 and 4A. pH of soils of Sheikhupura district in relation to the yield of rice



FIGS. 5 and 5A. Exchangeable sodium content (m. e.) of soils of Gujranwala district in relation to the yield of rice



FIGS. 6 and 6A. Exchangeable sodium content (m. e.) of soils of Sheikhupura district in relation to the yield of rice

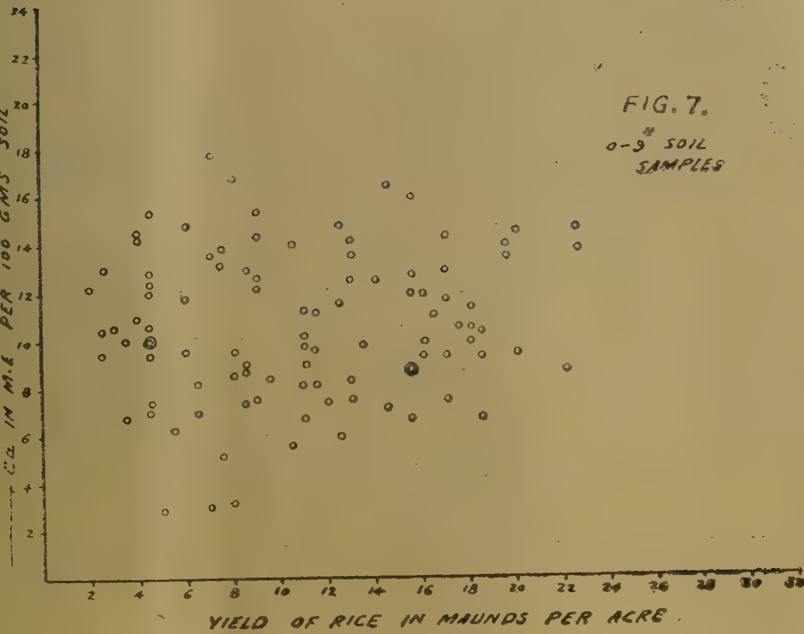
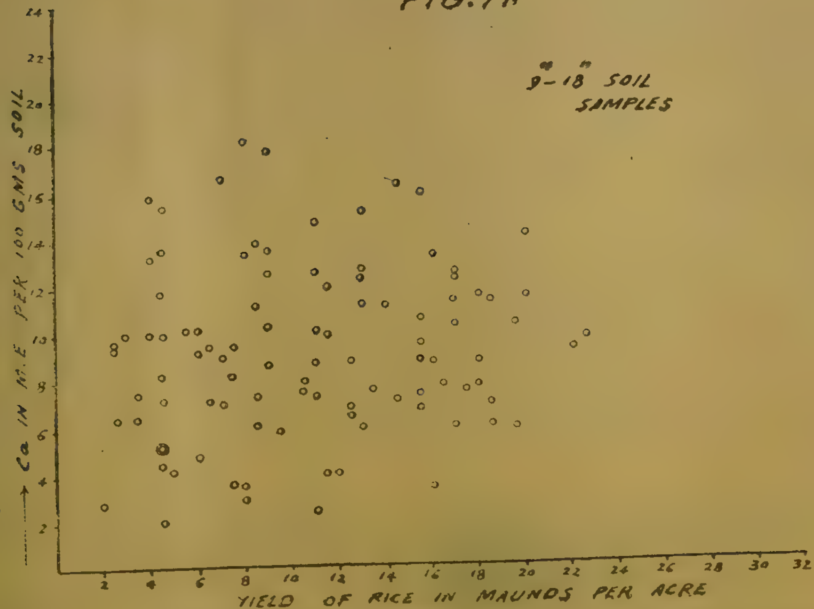


FIG. 7A



FIGS. 7 and 7A. Exchangeable calcium content of soils of Gujranwala district in relation to the yield of rice.

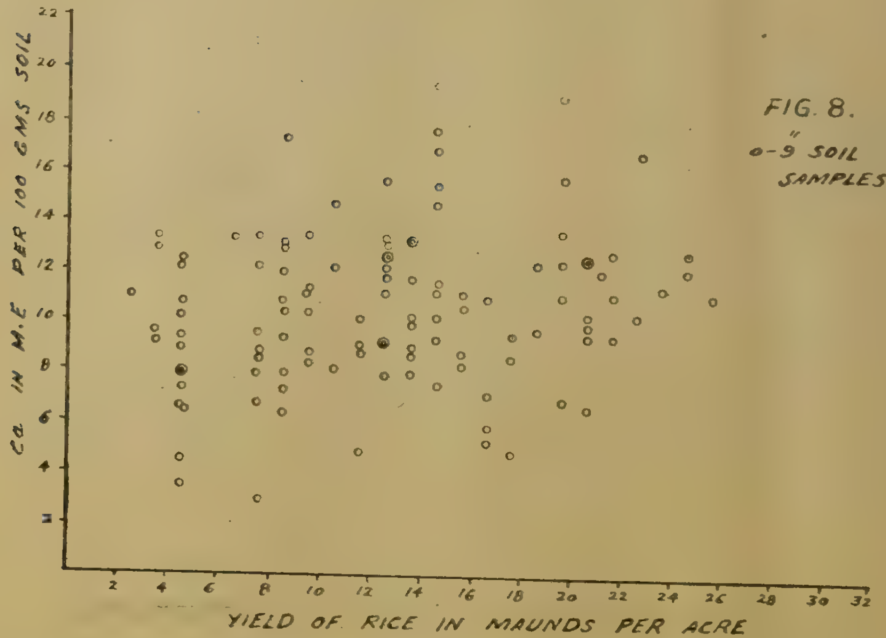
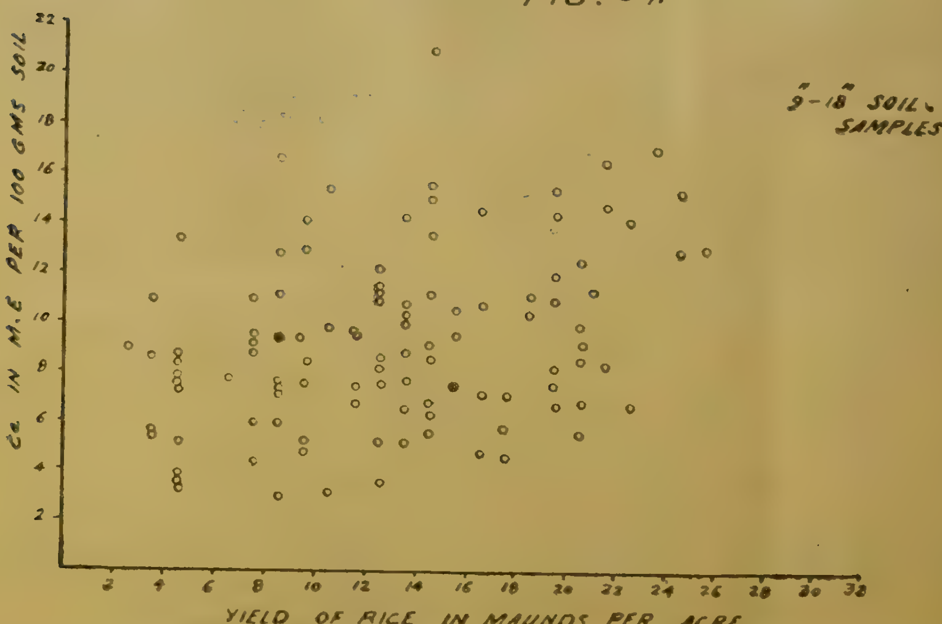
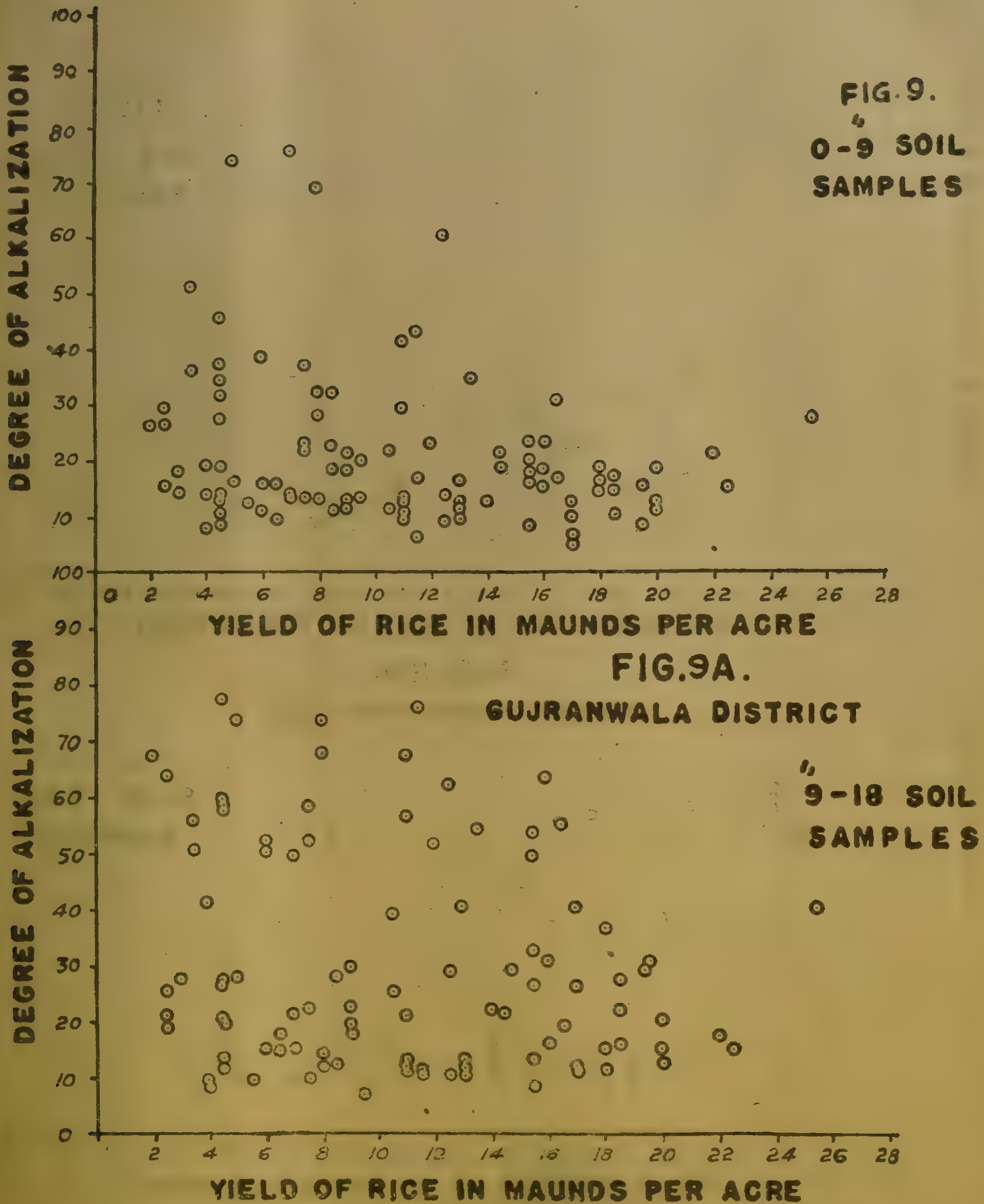


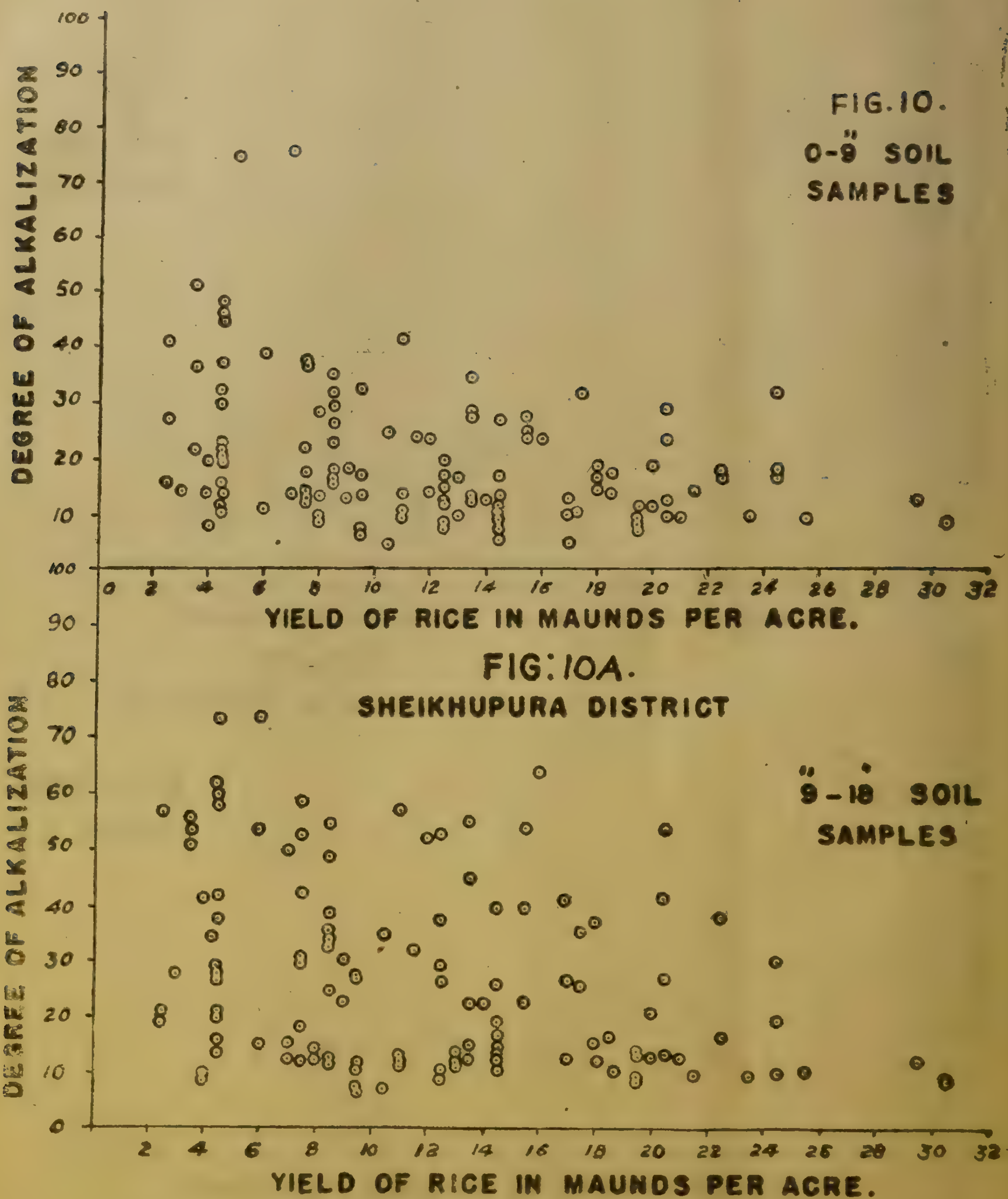
FIG. 8 A



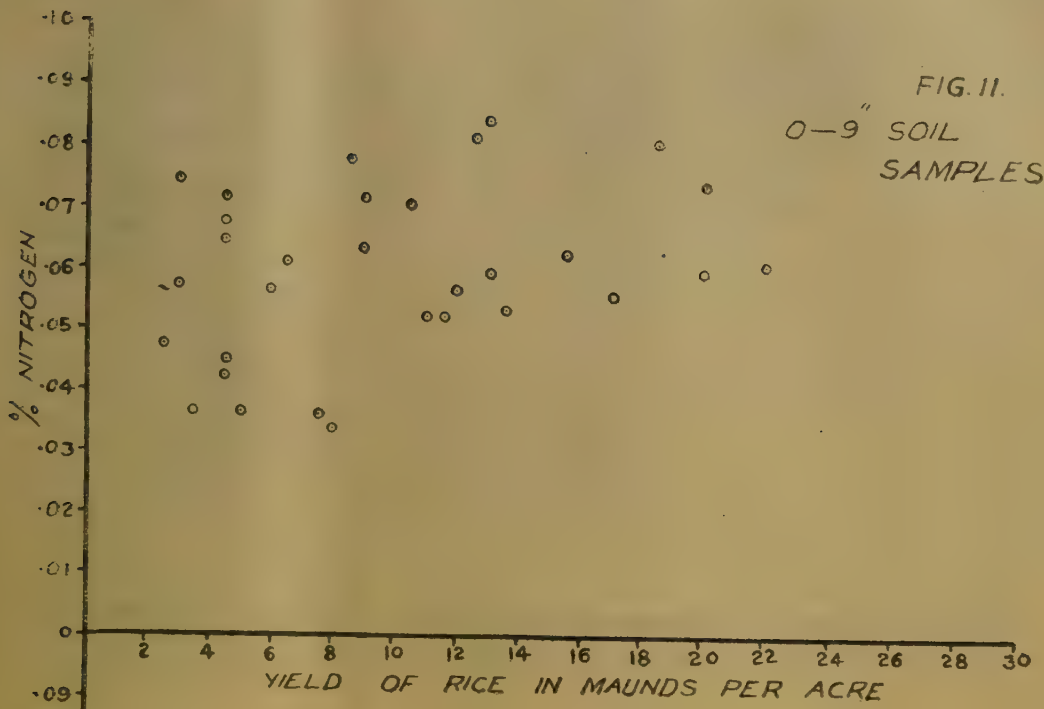
FIGS. 8 and 8A. Exchangeable calcium content of soils of Sheikhupura district in relation to the yield of rice

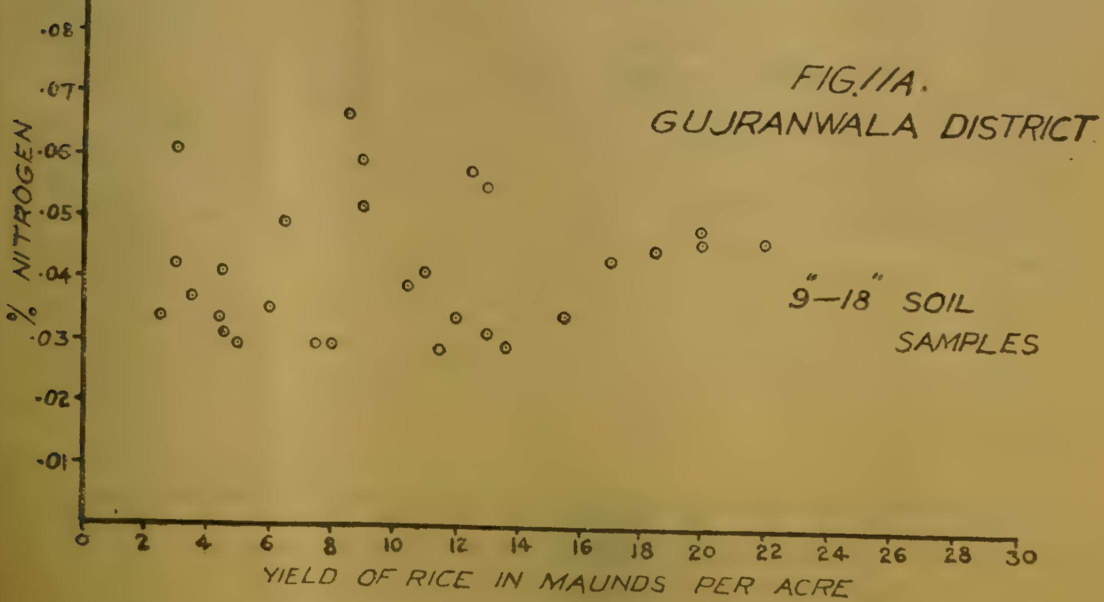


FIGS. 9 and 9A. Degree of alkalization of soils of Gujranwala district in relation to the yield of rice.

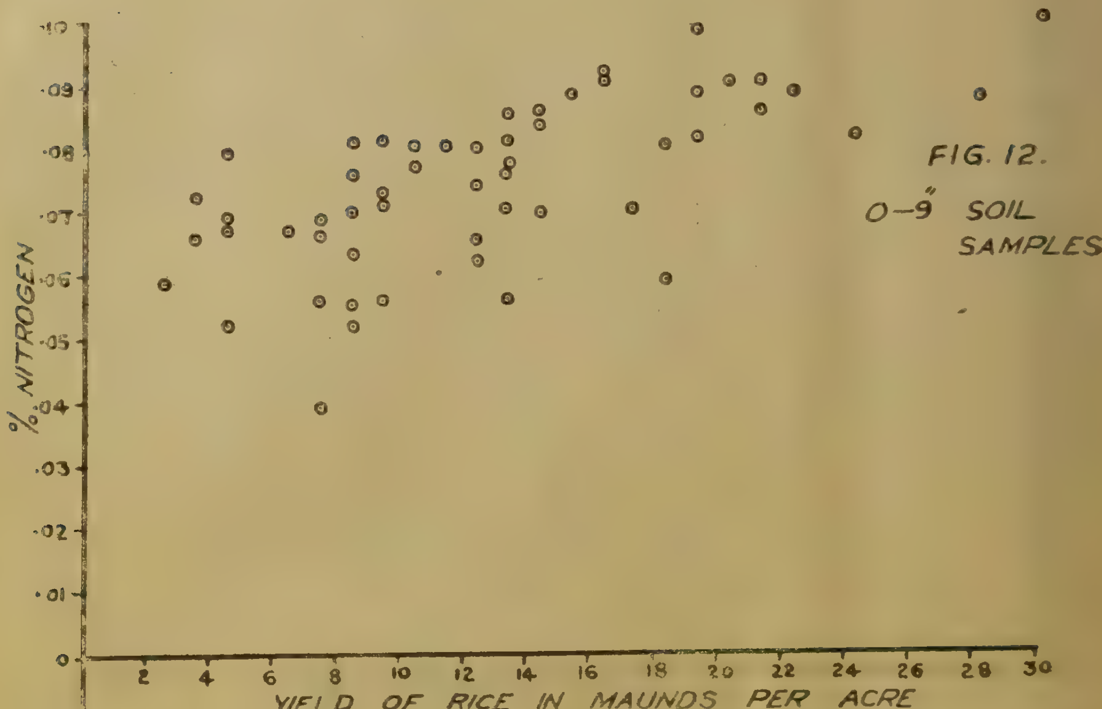


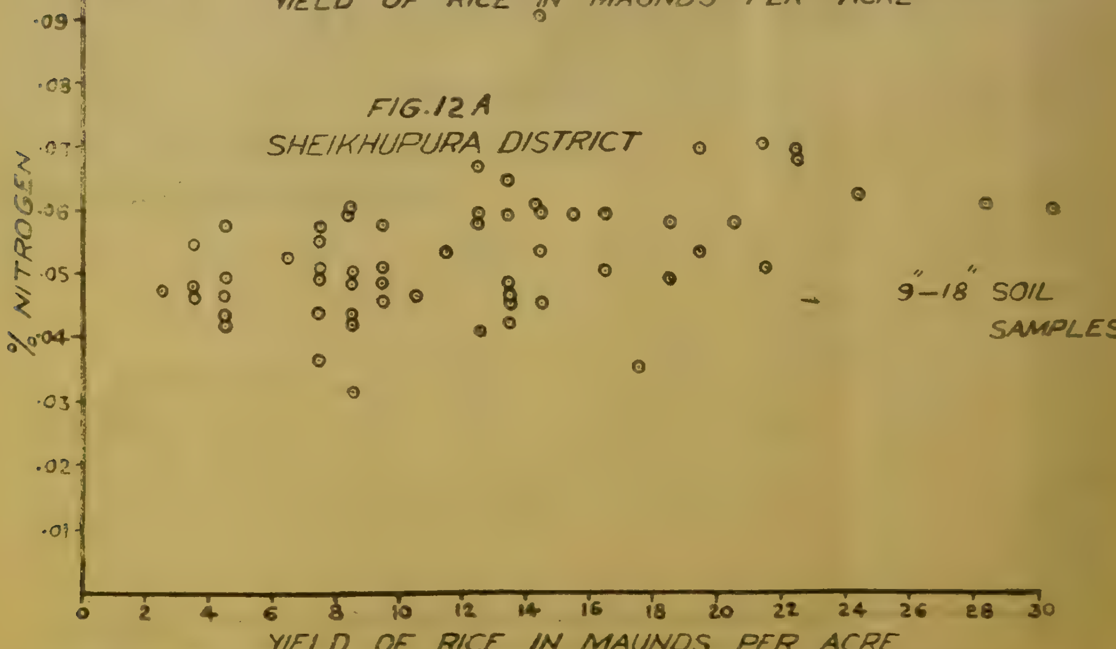
Figs. 10 and 10A. Degree of alkalization of soils of Sheikhupura district in relation to the yield of rice





FIGS. 11 and 11A. Percentage of nitrogen content of soils of Gujranwala district in relation to the yield of rice





Figs. 12 and 12A. Percentage of nitrogen content of soils of Sheikhupura district in relation to the yield of rice

FIG. 13.

0-9" SOIL SAMPLES

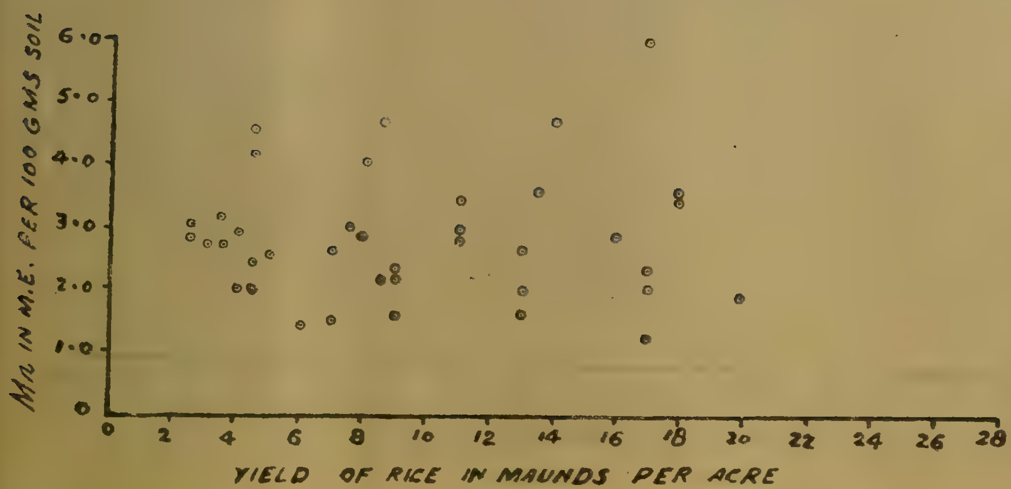
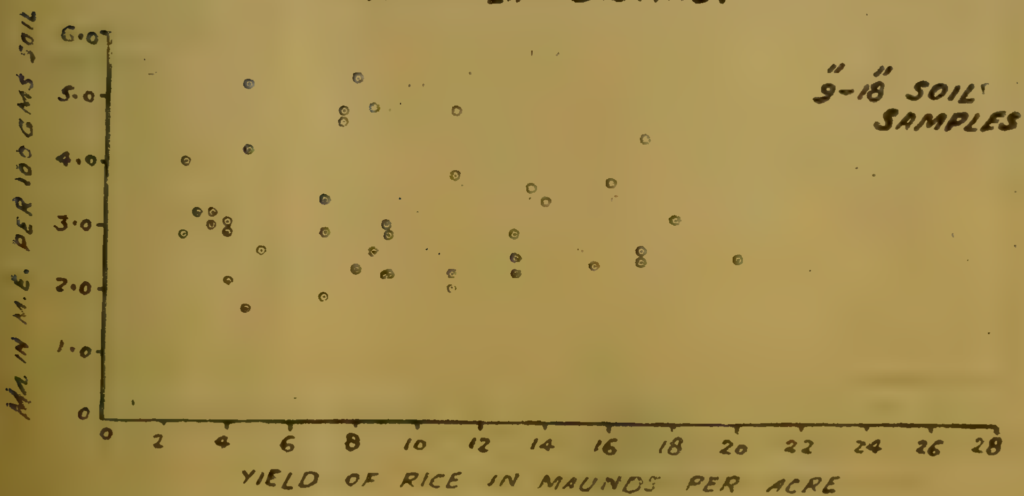
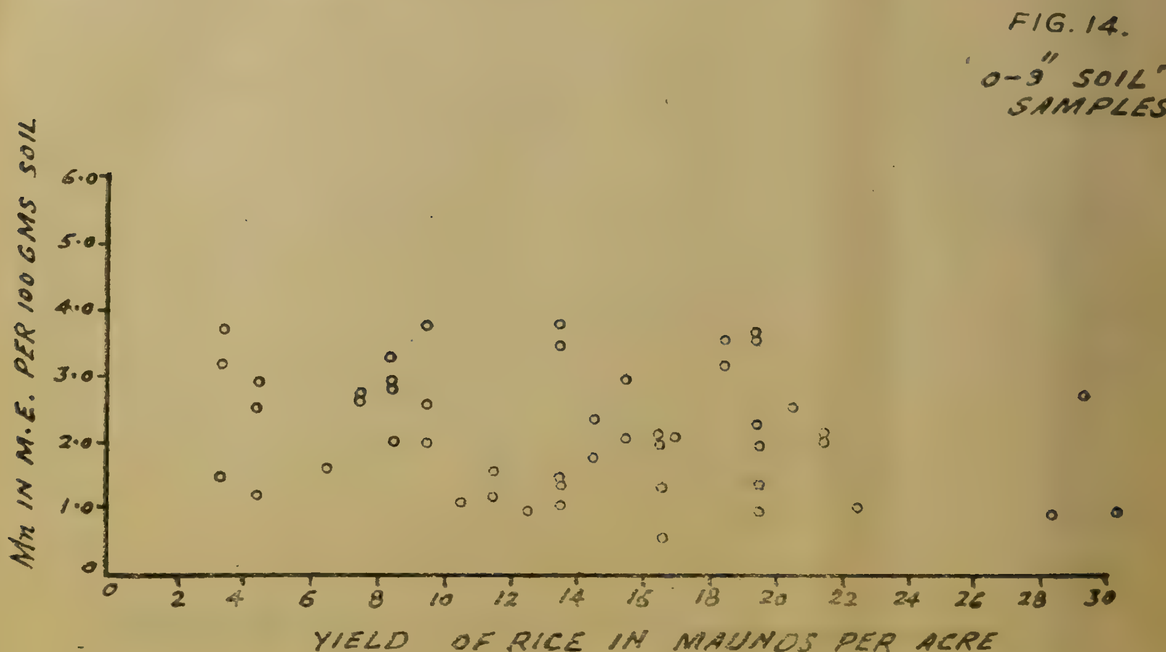


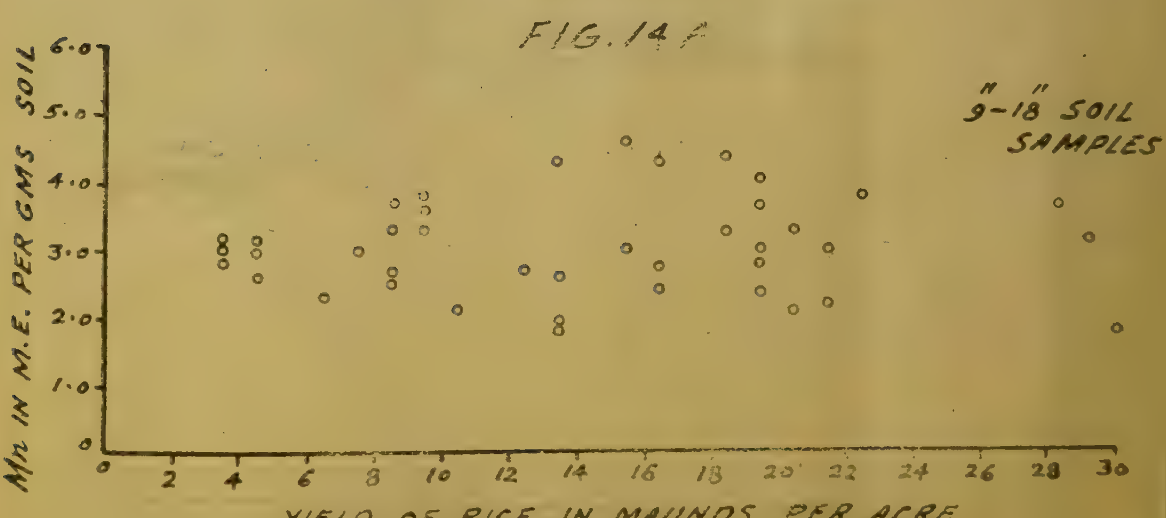
FIG. 13A

GUJRANWALA DISTRICT

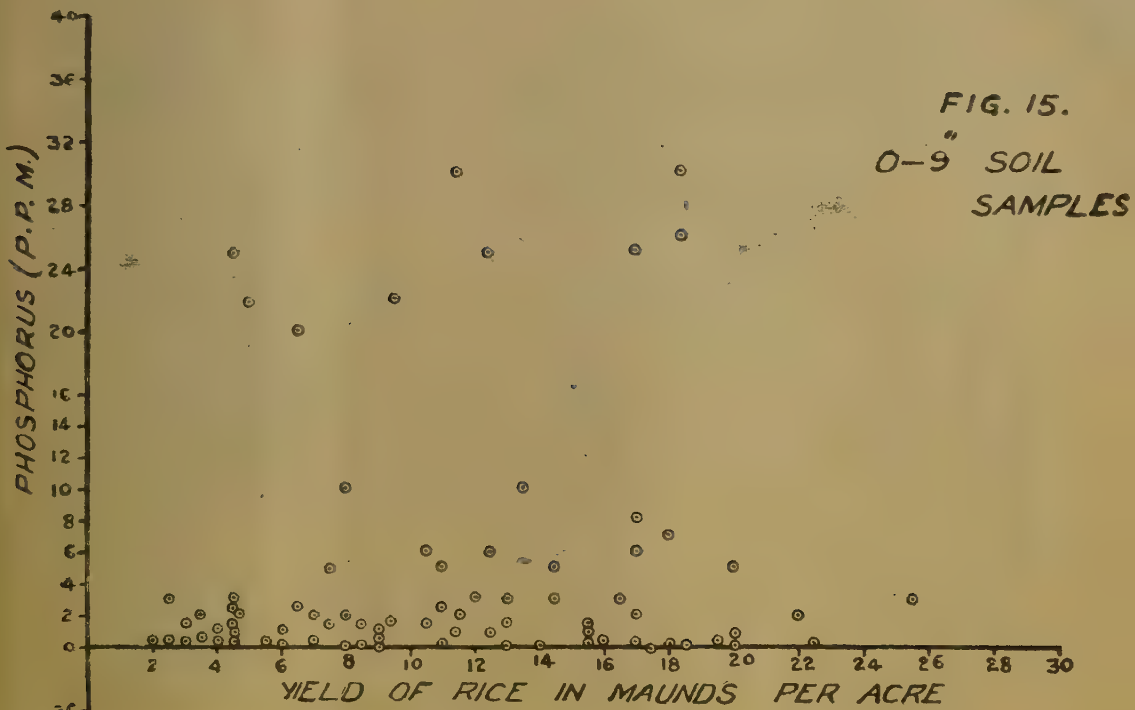


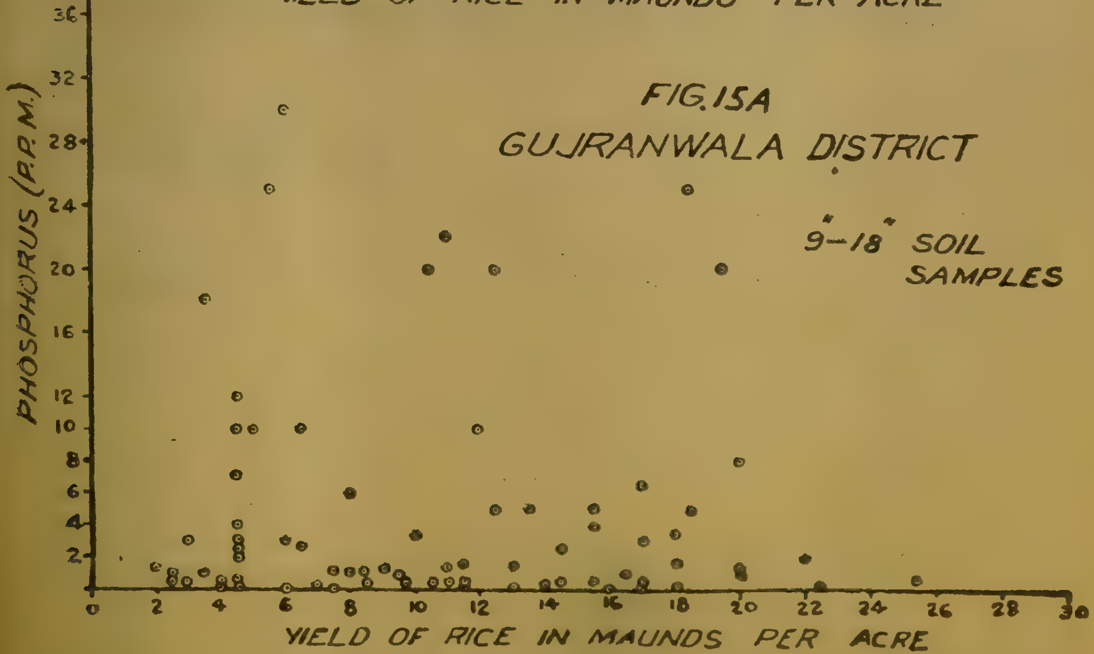
FIGS. 13 and 13A. Manganese content of soils of Gujranwala district in relation to the yield of rice



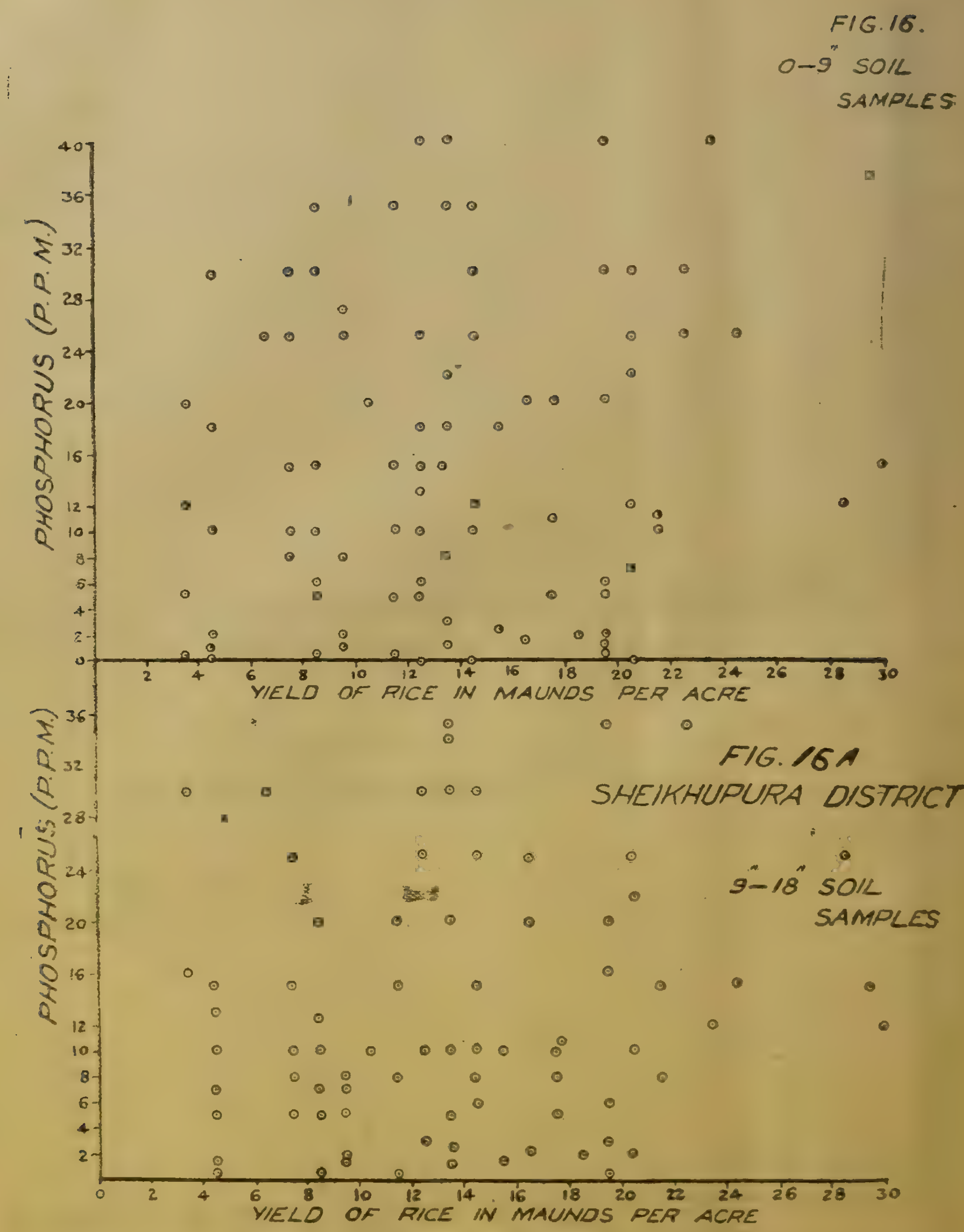


FIGS. 14 and 14A. Manganese content of soils of Sheikhupura district in relation to the yield of rice





Figs. 15 and 15A. Available phosphate content (p.p.m.) of soils of Gujranwala district in relation to the yield of rice



FIGS. 16 and 16A. Available phosphate content (p.p.m.) of soils of Sheikhupura district in relation to the yield of rice

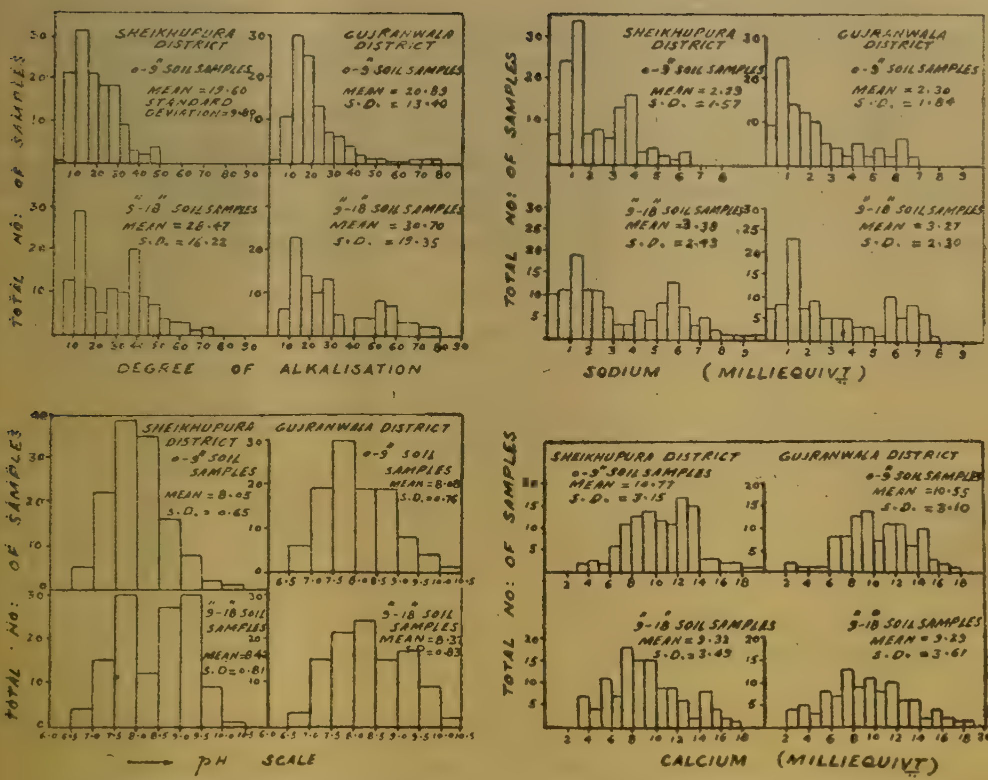


FIG. 17. Distribution of certain soils characteristics in rice areas of Gujranwala and Sheikhupura districts

Statistical treatments of analytical results

An examination of the Figs. 1-17 and 1A-16A brings out diagrammatically the sort of relationship between the yield figures and the main soil characteristics and seems to indicate sufficient scope for further elucidation on statistical basis particularly of the following :

(i) Soluble salts (above 0·2 per cent) for soils of Sheikhupura district only
(ii) *p*H
(iii) Exchangeable sodium and calcium base contents
(iv) Degree of alkalization
(v) Nitrogen content
(vi) Manganese content

Further, histrograms of (ii), (iii) and (iv) soil characteristics are presented in Fig. 17. The distribution of the results of the exchangeable sodium content and degree of alkalization are very skew indicating that the soils with low contents of those characteristics are more frequent than those of high contents.

The statistical analyses resulted in a number of correlations between the above-mentioned soil characteristics and the rice yield figures, which, for soils of Gujranwala and Sheikhupura districts, are given in Tables I and II respectively. Tables III and IV show some of the statistical constants relating to the multiple regression of the yield figures with certain characteristics of soils of those two districts respectively. The partial and multiple correlations of yield figures with *p*H and nitrogen content of soils of the two districts are given in Tables V and VI respectively.

Table I

Correlation of yield of rice with certain soil characteristics of the first and second 9 inches soil samples of Gujranwala district

Soil characteristics	No. of observations	Correlation of soil characteristic between 1st and 2nd 9 in.	Total 1st 9 in.	Correlation 2nd 9 in.	Multiple correlation
Degree of alkalization	105	0·6419†	—0·2175*	—0·1662	0·2202
*p*H	106	0·8084†	—0·3151†	—0·2472*	0·3151†
Sodium	104	0·7479†	—0·2015*	—0·1308	0·2038
Calcium	100	0·4616†	0·911	0·1046	0·1150
Nitrogen	31	..	..	0·2831[1]	..

[1] Correlation with the average value in the 1st and 2nd 9 in. soil samples
*Indicates significance at 5 per cent level
†Indicates significance at 1 per cent level

Table II

Correlation of yield of rice with certain soil characteristics of the first and second 9 inches soil samples of Sheikhupura district

Soil characteristics	No. of observations	Correlation of soil characteristic between 1st and 2nd 9 in.	Total 1st 9 in.	Correlation 2nd 9 in.	Multiple correlation
Degree of alkalization	128	0·6934	—0·2180*	—0·3151†	0·3153
*p*H	128	0·8460	—0·1380	—0·1638	0·1638
Sodium	128	0·6251	—0·1714	—0·2874†	0·2876†
Calcium	128	0·6088	0·2693†	0·3415†	0·3500†
Soluble salts	45/35	Not calculated	—0·0459	—0·0004	..
Nitrogen	66	..	..	0·6884[1] †	..

[1] Correlation with the average value in the 1st and 2nd 9 in. of soil
*Indicates significance at 5 per cent level
†Indicates significance at 1 per cent level

TABLE III

Some statistical constants connected with the multiple regression of yield of rice and certain characteristics of soils of Gujranwala district

No. of observation=98

Statistical constant	Yield	Degree of alkalization	pH	Sodium	Calcium
Mean	10·54	21·01	8·11	2·36	10·57
Standard error of mean	5·37	13·80	0·766	1·88	3·11
Correlation with yield (y)	..	0·2687	—0·3390	—0·2419	0·0830
Correlation with D.A.	..	..	0·5781	0·8191	—0·5038
Correlation with pH	..	..	..	0·7342	—0·1120
Correlation with Na	..	..	..	..	—0·2101
Multiple correlation of yield with D.A.	0·3682	..	..	..	..
Partial regression coefficient of yield	..	—0·1138	—2·5279	0·7190	—0·0894
Partial regression coefficient	..	—0·2921	—0·3602	0·2510	—0·0518
" t " for significance of partial regression coefficient	..	1·40	2·53**	1·17	0·42

N.B.—(1) The values of D.A., pH, Na and Ca taken are those in the 1st 9 in. of soil
(2) **denotes significance on 1 per cent level

TABLE IV

Some statistical constants connected with the multiple regression of yield of rice and certain characteristics of soils of Sheikhupura district

No. of observations=62

Statistical constant	Yield	Degree of alkalization	pH	Sodium	Calcium
Mean	12·03	26·05	3·23	10·19	641·58
Standard error of mean	5·66	10·63	1·87	3·12	113·06
Correlation with yield (Y)	..	—0·4425	—0·3067	+0·3909	+0·6788
Correlation with pH	..	..	+0·8049	—0·4926	—0·4276
Correlation with Na	..	..	..	..	+0·4064
Multiple correlation of yield with D.A., pH, Na and Ca.	0·6992	..	..	..	..
Partial regression coefficient of yield	..	—0·1614	+0·4780	+0·0460	+0·0290
Partial standard regression coefficient	..	—0·3027	+0·1579	+0·0253	+0·5796
" t " for significance of partial regression coefficient	..	1·47	0·85	0·20	5·36

N.B.—(1) The values of D.A., pH, Na and Ca are the average values of the 1st and 2nd 9 in. of soil
(2) **denotes significance on 1 per cent level

TABLE V

Partial and multiple correlation of yield of rice (Y) with pH and nitrogen, Gujranwala district

No. of observations=31

Statistical constant	Yield	*p*H	Nitrogen
Mean	9·81	8·47	500·61
Standard error of mean	5·55	0·866	111·62
Correlation with yield	..	—0·5511	0·2831
Correlation with *p*H	..	..	—0·6970
Partial correlation with yield	..	—0·5147	—0·1699
Multiple correlation of yield with *p*H and N	0·5690	..	..

N.B.—The values of *p*H and N are taken as the average value in the 1st and 2nd 9 in. soil samples

TABLE VI

Partial and multiple correlation of yield of rice (Y) with pH and nitrogen, Sheikhupura district

No. of observations=66

Statistical constant	Yield	*p*H	Nitrogen
Mean	13·03	8·26	649·26
Standard error of mean	6·78	0·681	114·26
Correlation with yield	..	—0·2629	+0·6884
Correlation with *p*H	..	..	—0·3459
Partial correlation with yield	..	—0·0364	+0·6600
Multiple correlation of yield with *p*H and N	0·6889	..	..

N.B.—(1) The values of *p*H and N are taken as the average value in the 1st and 2nd 9 in. soil samples
(2) The units in which the mean values are expressed are as below :
Y = Yield of Md./Acre
*p*H = already explained under Table III
N = Percentage

From the various statistical relations given in the tables it is apparent that any soil characteristic of the top nine inches sample is, generally speaking, positively correlated with the same characteristic of the second nine inches samples, i.e. a high content in the top samples means generally a high content in the second nine inches samples and vice versa.

THE EFFECT OF THE VARIOUS SOIL CHARACTERISTICS ON THE YIELD OF RICE

(*a*) *Soluble salt content of soils.* A comparison of the Figs. 1, 1A, 2 and 2A, in which the results of the soluble salt content of soils of the two districts are diagrammatically represented against the yield figures, shows that there are comparatively larger number of sites having soluble salt content higher than 0·2 per cent in Sheikhupura than in Gujranwala district. It may be of interest to further investigate the causes of this difference in the saline content of soils of the two districts. There is no definite statistical relationship between the yield of rice and soluble salt content of soils below 0·2 per cent. The statistical correlation between soils of Sheikhupura district having salt

content higher than 0·2 per cent and yield figures also works out to be insignificant as shown in Table II.

(*b*) p*H values of soils*. Figs. 3, 3A, 4 and 4A represent the relationship of yield figures and the *p*H of soils. The various statistical correlations are given in the tables. For soils of Gujranwala district, it is brought out that—

(i) The *p*H of the top and second nine inches soil samples bear a significant correlation with yield figures.

(ii) The partial regression coefficient is also very significant.

(iii) The total correlation coefficient for figures of *p*H and yield, i.e. 0·339 is not significantly different from the multiple correlation coefficient (0·364).

(iv) There exists a significant correlation between the *p*H of soils and the yield of rice, i.e. the greater the *p*H the less the yield and vice versa. This does not, however, mean that other soil characteristics have no effect on yield but they are so distributed in relation to *p*H that their effect is not markedly apparent.

(v) The regression formula for the yield figures (Y) in maunds per acre and the average value of *p*H of total depth of soil examined, i.e. 18 in., for Gujranwala district is :

$$Y = 39{\cdot}72 - 3{\cdot}53\ p\mathrm{H}.$$

It is rather interesting that there does not exist any significant correlation between *p*H and yield figures for soils of Sheikhupura district. The partial correlation of *p*H and yield figures for that district is also insignificant.

It seems, therefore, that *p*H of soils is one of the determining factors for the yield of rice as far as the soils of Gujranwala district only are concerned but not for those of Sheikhupura district.

(*c*) *Exchangeable base content of soils*. The contents of the main exchangeable bases, i.e. sodium, potassium, calcium and magnesium were determined for all soil samples. The results of the exchangeable sodium and calcium contents of soils, which only seemed to yield significant statistical relationships, have been plotted against respective yield of rice figures in Figs. 5-8 and 5A-8A for the top and second nine inches soil samples respectively of the two districts.

The main conclusions regarding the effect of exchangeable base content of soils and the yield figures are :

(i) The correlation between the yield figures and the sodium content of the top nine inches soil samples of Gujranwala district is significant but that with the calcium content of those soils is insignificant.

(ii) The correlations of the calcium content of the top and 2nd nine inches soil samples of Sheikhupura district with respect to yield figures are significant and so is the correlation of the sodium content of the second nine inches soils of that district.

(iii) The multiple correlations of sodium and calcium are not significant for soils of the two districts.

(*d*) *Degree of alkalization*. Degree of alkalization is defined as the ratio of the amount of exchangeable monovalent ions (Na + K) in the soil to maximum amount of monovalent ions the soil is capable of binding [Puri, 1933]. It appears that, where exchangeable sodium is the limiting factor, the yield of rice shows a significant correlation with this value also.

The results of the degree of alkalization for the top and second nine inches soils of the two districts are plotted in relation to the yield figures in Figs. 9, 9A, 10 and 10A and the statistical correlations are presented in the various tables. It is seen that whereas the statistical correlations between the yield figures and the degree of alkalization of both the top and second nine inches soils are significant for samples of Sheikhupura district those for soils of Gujranwala district are only significant for the top nine inches and not for the 2nd nine inches soil samples. This difference in the behaviour of the soils of the two districts is rather interesting.

(*e*) *Total nitrogen content of soils*. The results of the percentage nitrogen content of soils in relation to the yield figures are plotted in Figs. 11, 11A, 12 and 12A for the top and second nine inches soil samples respectively of the two districts. The statistical correlations have been worked out on the basis of the average nitrogen content for the whole 18 inches depth of soil and given in

the tables. There were 66 and 36 observations for Sheikhupura and Gujranwala districts respectively. As shown in Table II, the multiple correlation figures are also highly significant. The corresponding correlation figures for soils of Gujranwala districts are, however, not so significant. Unlike the behaviour of soils of Gujranwala district, therefore, it is the nitrogen content of soils which determines the yield of rice in Sheikhupura district. It does not mean, however, that other soil characteristics have no influence on the yield of rice but they are so distributed in relation to the nitrogen content that their effect does not seem to be as marked as that of nitrogen content of soil. The regression formula for the yield figures (Y) and the nitrogen content of soil (N) is as follows :

$$Y = 0{\cdot}0408\ \mathrm{N} - 13{\cdot}49$$

(*f*) *Manganese content of soils.* The results of the manganese content of soils in relation to the yield figures are plotted in Figs. 13, 14, 13A and 14A for the top and second nine inches soil samples of the two districts. The statistical correlations are given below :

Name of district	*Top 9 in. soils*	*Second 9 in. soils*
Gujranwala	+0·0305	—0·0702
Sheikhupura	—0·2106	+0·0594

The correlations are not significant which implies that, as far as the yield of rice is concerned the manganese content of soils is not a determining factor for soils of any of the two districts. A very significant negative correlation between the yield of wheat and this soil characteristic was found for wheat soils reported in the previous publication [1941] relating to wheat soils.

(*g*) *Available phosphate content of soils.* The results of the available phosphate content of soils in relation to the yield of rice are graphically represented in Figs. 15, 15A, 16 and 16A. A comparison of the figures for the two districts brings out one very interesting difference. The soils of Gujranwala district have a comparatively much lower available phosphate content than those of Sheikhupura district. It may be of interest to investigate further the cause of this difference in the available phosphate content of soils of those two districts. Also on the whole, the available phosphate content of soils, under present investigation, are lower than those of wheat soils reported in the previous publication.

As is apparent from the diagrams, the available phosphate contents of soils do not seem to bear any relation to the yield of rice figures and hence no attempt has been made to work out the relationship statistically. As far as this soil characteristic is concerned there again exists a very conspicuous difference in respect to its effect on the rice and wheat yields. In the latter, a very significant positive correlation was found to exist between the available phosphate content of soils and the yield of wheat.

(*h*) *Boron content of soils.* The results of the boron content of soils do not seem to indicate any relation to the yield of rice. No statistical correlation was, therefore, obtained in this case.

Conclusion

The statistical interpretation of the effect of the various characteristics on the yield of rice for the top (A) and the second (B) nine inches soils samples of the two districts are summarized in tabular form below :

Soil characteristic	Soils of Gujranwala district	Soils of Sheikhupura district
*p*H . .	Significant for both A and B	Not significant
Na . .	Significant for A only	Significant for B only
Ca . .	Insignificant	Significant for both A and B
D.A. . .	Significant for A only	Significant for both A and B
N . . .	Insignificant	Highly significant

Summary

The top and second nine inches soil samples from rice areas in Gujranwala and Sheikhupura districts of the Punjab have been analysed and the results of the analyses employed for determining the statistical correlations with the figures for yield of rice at those sites. It is brought out that the soil characteristics which manifest significant correlations with yield are *p*H, exchangeable sodium and degree of alkalinity for soils of Gujranwala district and exchangeable calcium and sodium, degree of alkalinity and nitrogen for soils of Sheikhupura districts.

The manganese and available phosphate contents of soils do not seem to affect the yield of rice which is at variance to what has been reported for wheat soils of the Punjab in the previous publication.

Acknowledgement

The authors take this opportunity to express their thanks to Mr M. L. Mehta, Director, Land Reclamation, Punjab, for his interest in the present work and to Messrs Bhagwan Singh and Gian Parkash, Research Assistants, for the field work so nicely done by them in short time at their disposal.

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THE WILT DISEASE OF PIGEON PEA [*CAJANUS CAJAN* (L.) MILLSP.] WITH SPECIAL REFERENCE TO THE DISTRIBUTION OF THE CAUSAL ORGANISM IN THE HOST TISSUE *

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(Received for publication on 13 November 1945)

I. Introduction

FROM the time when the wilt disease of pigeon pea (*Cajanus cajan*) was first investigated by Butler, it has been known that the causal fungus *Fusarium udum* Butler forms frequently on the surface of the bark of diseased plants masses of salmon-pink spores which may be either macro- or micro-conidia. The author, while studying the disease, found that spore masses could often be observed in the branches of the diseased plants to a height of several feet. It was also observed that the disease may at times become manifest through the wilting of individual branches. The spores which are found mainly in the axes of branches, germinate readily under favourable conditions.

*This investigation was carried out in partial fulfilment of the requirements for the Diploma of Associateship of the Imperial Agricultural Research Institute, New Delhi

It is questionable to what section of *Fusarium* the causal organism belongs. It was for a time regarded as a race of *Fusarium vasinfectum* Atk., which would place it in the section Elegans. Padwick [1940], however, showed that in several respects *F. udum* differed sharply from *F. vasinfectum* and considered it a good species. Wollenweber [1938] described as *F. lateritium* var. *uncinatum*, a fungus which Padwick [1940] showed to be identical with *F. udum*. The placing of the fungus in *F. lateritium*, to which it has much resemblance, would bring it within the section Lateritium. Section Elegans contains most of the wilt causing organisms which invade the plants through the roots. Section Lateritium has fungi which have the habit of establishing themselves on the surface of tissue of above ground parts of plants.

The presence of large spore masses on the bark of affected plants, and the close resemblance of *Fusarium udum* to species of the section Lateritium, raises the question whether such spores, spread either by wind or, which is more likely, by rain-, flood-, or irrigation-water, establish themselves on the surface of the tissue and then invade it, giving rise to the observed phenomenon of wilting in individual branches. The woody nature of the host plant does not lend itself to a direct study of the question. However, an indirect approach was possible. If the spore masses appear on the surface of the tissue at points above the places at which the fungus is found within the vessels, it is likely that infection has taken place from the outside. If on the other hand, infection of the vessels is found always in advance of the appearance of the spore masses externally, it must be presumed that the latter is a post-mortem phenomenon, the fungus having advanced through the vessels, then destroyed the cortex, and sporulated externally. An examination was therefore made of a large number of branches in plants in various stages of the disease to compare the internal spread of the fungus with its external production of spores.

II. Internal and external distribution of the fungus

From an infested field, plants in various stages of the disease were collected and were classified as follows :

(1) Plants which have long died, showing the superficial pink colorations to some height, but bearing no pods and seeds ; (2) plants which have long died, showing the superficial pink colorations to some height, but bearing pods and seeds ; (3) plants which have freshly wilted, having one or more branches affected ; (4) normal, healthy plants. These groups of plants were named A, B, C and N respectively. Out of these four categories of plants, four plants of group A, four of B, five of C and five of N were selected for this experiment. Isolations, starting from the ground level, were taken at every sixth inch in height, including the various primary branches. In the plants which had freshly wilted, at every height two corresponding isolations were taken from diametrically opposite points on the stem, one line of isolation being restricted to that side of the stem showing black streaks either on the bark or on the wood. This was done to ascertain if the fungus was specially located in those regions of the stem wherefrom the branches had wilted.

To determine the internal spread of the fungus, marks were made at every sixth inch of the plants, and from every such point, starting from the ground level, wood of $\frac{3}{4}$ in. in length was cut off. Then the bark was completely removed with a pen-knife and the wood was longitudinally split into five sticks. These sticks were then placed in one per cent silver nitrate solution for one minute and washed in two per cent sterilized solution of sodium chloride for two minutes and were finally placed in five tube slants containing potato dextrose agar. After a fortnight when the fungus grew in culture, it was examined under the microscope and note was made when *F. udum* had grown out of the sticks.

To determine the external vertical distribution of the spores, scrapings from the surface of plants belonging to group A, B and C were taken at various heights. The slides so prepared were examined under the microscope to see if any spore of *F. udum* was present.

The results of the above experiment are indicated in Tables I, II and III.

TABLE I

Isolations from plants of group A

(Plants long dead, without pods and seeds)

Plants	Branches	Total height in feet	External distribution in feet	Internal distribution in feet
A_1	Main stem	9·0	6·4	7·5
	b_1 (branch 1)	7·2	4·8	7·0
	b_2	7·0	4·6	6·5
	b_3	8·0	5·1	7·5
A_2	Main	7·5	4·5	6·5
	b_1	7·0	2·2	5·0
	b_2	7·2	4·2	6·5
	b_3	7·0	1·3	5·0
A_3	Main	8·7	4·0	6·5
	b_1	8·7	3·8	7·0
	b_2	7·4	1·7	4·5
	b_3	8·3	4·0	5·5
	b_4	6·6	5·0	6·5 (topmost)
	b_5	5·5	4·2	5·5 (topmost)
	b_6	8·2	6·0	8·0 (topmost)
A_4	Main	7·7	5·9	6·5
	b_1	8·7	6·0	8·0
	b_2	8·1	5·5	6·0
	b_3	8·5	5·5	7·5

TABLE 11

Isolations from plants of group B

(Plants long dead, with pods and seeds)

Plants	Branches	Total height in feet	External distribution in feet	Internal distribution in feet
B_1	Main	10·0	4·1	10·0 (topmost)
	b_1	[illegible]	[illegible]	7·0
	b_2	6·2	2·5	4·5
	b_3	8·3	3·0	4·0
	b_4	9·0	3·3	7·0
	b_5	6·3	2·5	3·5
B_2	Main	8·0	0·5	2·5
	b_1	7·2	*nil*	1·0
	b_2	5·3	*nil*	*nil*
B_3	Main	9·5	1·0	3·0
	b_1	9·1	*nil*	1·0
	b_2	8·0	*nil*	*nil*
B_4	Main	9·0	3·3	9·0 (topmost)
	b_1	8·5	1·9	8·5 (topmost)
	b_2	8·2	2·08	6·5
	b_3	7·0	2·2	6·0
	b_4	7·7	4·5	7·0

TABLE III

Isolations from plants of group C

(Plants freshly wilted)

Plants	Branches	Total height in feet	External distribution in feet	Internal distribution on the line of wilted branches	Internal distribution on the line diametrically opposite to that of wilted branches
	Main	9·0	*nil*	1·0	*nil*
C_1	b_1	6·5	„	*nil*	X
	b_2	8·5	„	„	X
	b_3	7·5	„	„	X
	b_4	8·0	„	„	X
	Main	9·0	*nil*	1·5	*nil*
	b_1	9·0	„	0·5	X
C_2	b_2	8·5	„	*nil*	X
	b_3	7·0	„	2·0	X
	Main	9·5	*nil*	0·5	*nil*
	b_1	8·0	„	1·0	X
C_3	b_2	6·5	„	*nil*	X
	b_3	8·5	„	„	X
	Main	9·0	*nil*	0·5	*nil*
	b_1	8·5	„	*nil*	X
C_4	b_2	8·5	„	2·5	X
	b_3	7·0	„	*nil*	X
	Main	9·5	*nil*	0·5	*nil*
	b_1	9·0	„	2·5	X
C_5	b_2	8·0	„	*nil*	X
	b_3	8·5	„	„	X

The results in Tables I and II show that the fungus, in infected branches both externally and internally, is always traceable without any discontinuity from the base upwards, and the internal vertical spread of the fungus is always higher than that of the external. Secondly in some branches of some plants belonging to the group A, as well as to group B, the fungus reaches internally the top showing the possibility of its further spread into the pods and the seeds.

The results in Table III show that the fungus is always present at different heights of isolation without any discontinuity and this can only be located on the side of the stem having blackened areas. On the other hand, it cannot be traced in the diametrically opposite side of the stems which have not been so blackened, and where the branches do not show any sign of wilting. The fungus is always traceable right from the base upwards to a height 2-2½ feet.

The isolation experiments on the normal, healthy plants show the absence of fungus both externally and internally.

The possibility of seed transmission

Many *Fusaria* causing wilt diseases in various plants are known to be seed borne. Orton [1931] lists about 15 such species carried on about 16 different host plants. Since the publication of the paper by Orton [1931], various other cases about the seed-borne nature of *Fusaria* have also come to our notice. Kendrick [1931, 1934] has shown that the wilt of cowpea and the yellows of beans, caused by species of *Fusarium*, are transmitted through the seeds. Kadow and Jones [1932] and Snyder [1932] have shown that the *Fusarium* wilt of peas is of similar nature. Taubenhaus and Ezekiel [1932] have shown that the cotton wilt organism is seed-borne. In India, Kulkarni [1934] has shown the seed-borne nature of cotton-wilt fungus. Mitra [1934] has proved that the *Fusarium* involved in wilted sunn-hemp is carried externally on the seeds. On the other hand, Uppal and Kulkarni [1937] have produced experimental evidence that the sunn-hemp wilt fungus can be carried both externally and internally through the seeds.

In pigeon-pea the seed transmissibility of the *Fusarium* is not definitely known. Butler [1918] writes that there is no evidence to prove that the wilt producing fungus in pigeon-pea is seed-borne. McRae [1924, 1926] showed that the bulk of infection does not come through the seeds; but this statement does not eliminate the idea that the fungus may be carried through the seeds. Moreover, McRae [1924] has shown that when the surface sterilized seeds were sown in presumably disease-free plots, the percentage of wilt was 0·04 per cent. This fact does not disprove that the fungus may be carried through the seeds. Furthermore, from the symptoms, a strong parallelism of pigeon-pea wilt to that of the cotton wilt is suggested. Kulkarni [1934] writes that in wilted cotton plants, the fungus spreads inside the diseased plants to the top, passing through pedicles into the seeds. In many cases also the fungus fails to reach the pedicles. In pigeon-pea almost a similar state of affairs takes place. The previous isolation experiments show that the fungus in many cases spreads internally to the top of the branches and there is every possibility of the organism spreading further into the pods and the seeds. Therefore, it was thought worthwhile to carry on experiments to ascertain if the fungus is borne inside the seeds of the diseased pigeon-pea plants.

In the topmost branches, the plant stem becomes gradually thinner and thinner and the isolation from these branches becomes difficult. Moreover, during the process of collecting the dead plants from the field, many of these thin branches break and fall down. Therefore to take isolations further upwards to the very base of the pods, becomes increasingly difficult and sometimes impossible. Hence it was thought desirable to study the seed transmissibility of the disease by direct methods.

We know that a fungus may be carried either externally or internally through the seeds; but the question of external seed transmission of the disease is not considered here because in the diseased plants which have long died there are abundant spores on the plant surface. During husking operations, there is every chance of the seeds getting contaminated with the spores from these diseased plants. Therefore the superficial transmission of the disease through the seeds will not be surprizing. With this assumption the experiment was confined to the study of the internal transmission of the disease in the seeds of the diseased plants.

Seeds from the diseased and healthy plants in the field were collected and they were classified into three groups as follows: (1) those from plants which have long died, having superficial pink coloration to considerable heights of about six feet; (2) those from the freshly wilted plants; (3) those from the normal healthy plants. These groups were designated B, C and N respectively. The seeds were surface-sterilized by immersing them for five minutes in 1 : 320 formalin solution and washing thoroughly in sterilized water.

In laboratory experiments, the sterilized seeds were placed in tube slants containing potato-dextrose-agar medium. Five hundred seeds of the group B and 300 seeds of group C, were thus treated. In all the 800 tubes, although the seeds swelled and burst in course of a fortnight, there was no indication of the fungus living inside the seed.

For pot-culture experiments, the soil taken from the field was soaked with water half an hour before sterilization and was sterilized by keeping it for one hour under 25 lb. of steam pressure. Then pots of convenient size were sterilized by dipping them for three to four minutes in a bucket of 1 : 320 formalin solution and these pots were filled up with the sterilized soil. Four hundred seeds of group B, 800 seeds of group C and 400 seeds of group N, were selected and immediately after their surface-sterilization they were sown, eight seeds in each of the pots. The seeds were sown on 3.7.1941 and the plants emerged from the soil after a week. The plants were kept under observation till 10.11.1941 when they were about 16 weeks old, and then the experiment was discontinued.

It was found that out of 400 seeds of group B, only 200 seeds were able to germinate, out of 800 seeds of group C, only 747 and out of 400 seeds of group N, only 350 seeds germinated.

In none of the plants raised from seeds of any class, was there any indication of wilt within the period of 16 weeks during which the experiment was conducted.

It was noted that the plants raised from the seeds of freshly wilted and healthy plants, were tall, robust, profusely branched and healthy looking; but the plants raised from the seeds of group B, were dwarfed, sparsely branched and not very vigorous. The average height of these plants after a period of 16 weeks was about four to five feet, whereas the height of the others was about six to seven and in some cases rising to eight feet.

The effect of temperature on survival and germination of spores formed on the surface of diseased plants

In an advanced state of the disease it is seen that the fungus comes to the surface of the plants and sporulates there freely. The majority of the spores are micro-conidia. These aerial diseased parts bearing abundant inoculum of spores, may prove to be potential sources of danger in the primary infection and perpetuation of the disease in a field, if these exposed spores remain viable from year to year. It is, however, expected that under natural conditions, of which the temperature is important, these surface exposed spores may be affected in their viability and germinability. In the experiments recorded here, the behaviour of micro-conidia at different temperatures was studied.

(*a*) *Determination of a suitable temperature for germination of micro-conidia.* From the surface of a diseased plant spores were scraped, and a suspension to a suitable concentration was made in sterilized water. One c.c. of this spore suspension was then poured and spread on the surface of a plain agar plate previously prepared. It was found by trial that the use of a synthetic medium encouraged free bacterial growth, and acidification of media with lactic acid did not check the bacterial growth satisfactorily without affecting the fungus spores. In the plain agar medium it was found that the bacterial growth was not so rapid. Furthermore, it was observed that when the spore suspension was mixed with the melted agar and then plated out, spores were very naturally placed at different depths of the medium in the same plate and under a particular field and under a particular focus, some spores came rightly to the focus, some slightly so and some not at all. This interfered with the counting of the germinating conidia. Therefore, in previously plated agar plates, 1 c.c. of the spore suspension was poured and uniformly spread, the extra water being poured off. These plates were then incubated at temperatures of 10°C., 15°C., 25°C. and 35°C., and the number of spores germinated was counted after 17 hours, 22 hours and 25 hours. The results of the experiment are indicated in Table IV.

TABLE IV

The percentage of germinated micro-conidia at different times under different temperatures

Temperature at which the plate was incubated	Average percentage of germination after 17 hours of incubation	Average percentage of germination after 22 hours of incubation	Average percentage of germination after 25 hours of incubation
10°C.	*Nil*	18·5	40·0
15°C.	26·1	33·0	58·4
25°C.	60·4	38·2	40·0
30°C.	67·1	55·0	41·7
35°C.	43·3	55·3	53·0

From Table IV it is observed that under all temperatures tried the percentage of germination falls down after 22 and 25 hours. This is because by this time, at these temperatures, considerable mycelial growth takes place and the mycelia begin to produce fresh conidia. Thus as the time passes on, the percentage of freshly produced conidia increases and this phenomenon is responsible for the low percentage counts in germination as the time is lengthened. Moreover, the rate of production of micro-conidia increases with the temperature, and the longer the duration of exposure, the greater is the disparity in the number of spores at the lowest and the highest temperature. Therefore the results on the percentage of germination became irregular after 22 and 25 hours of incubation and at these temperatures, the data as seen in Table IV, cannot be regarded as reliable. Moreover, at higher temperatures of 30°C. and 35°C., considerable bacterial growth takes place, and this goes on increasing with time and interfering with the counting. Hence the percentage of germination counted after 17 hours was regarded as fairly reliable and the conclusions were made thereon.

Analysis of the data after 17 hours shows that with the increase of temperature the percentage of germination, starting with zero at 10°C., increases up to 30°C. and then declines at 35°C. In other words, the percentage of germination is highest at 30°C. All subsequent spore germination studies were undertaken at the temperature of 30°C.

(*b*) *The effect of maintained temperatures on the germination of micro-conidia.* The pigeon-pea plants are harvested generally in the months of April and are sown in the months of June and July. The dead and the diseased residual aerial parts of the plants lie above or buried in the ground or are carried by some disseminating agent to other fields. After the month of April ungerminated conidia exposed on the source of the diseased plants have to pass through a critical period of summer months. Under local conditions of Delhi, the range of shade temperature varies from 30°C. to 45°C. in May and June, but the spores lie exposed in the sun at still higher temperatures. It is of interest to study if these surface-borne micro-conidia outlive the summer months and help in the perpetuation of the disease and in bringing about fresh infestations in the subsequent seasons. With this end in view the effects of maintained temperatures on the germination capacity of the micro-conidia were studied.

Some diseased stems of pigeon-pea having abundance of micro-conidia on the surface were collected from the field on 21.3.1942 and the materials were cut to a suitable size. These stem-pieces were divided into four lots, one lot being kept in the laboratory exposed to the natural temperature conditions. Out of the three lots left one was kept in 10°C., another in 15°C., and the last in 20°C. First reading on the percentage of germination was taken on 21.4.1942, after their incubation for a month; the second reading taken on 20.7.1942, after four months of incubation and the last reading on 15.8.1942 after an incubation period of nearly five months. The technique followed in counting of germination percentage was the same as followed in case of determining a suitable temperature for the germination of micro-conidia. The results of the experiments are indicated in Table V.

TABLE V

Readings after different hours at 30°C. taken on the average percentage of germination of micro-conidia after they were subjected to different temperatures for a period of one month (21.3.1942 to 20.4.1942)

Constant temperatures to which spores were subjected	Average percentage after 8 hours	Average percentage after 10 hours	Average percentage after 12 hours	Average percentage after 15 hours
10°C.	57·3	74·78	85·1	89·7
15°C.	55·7	57·78	55·3	79·6
20°C.	32·8	55·3	62·4	77·0
Normal room temperature .	26·0	48·7	63·0	64·6

TABLE VI

Readings after different hours at 30°C. taken on the average percentage of germination of micro-conidia after they were subjected to different temperatures for a period of four months (21.3.1942 to 20.7.1942)

Constant temperatures to which spores were subjected	Average percentage after 8 hours	Average percentage after 10 hours	Average percentage after 12 hours	Average percentage after 15 hours
10°C..	14·6	25·9	31·4	41·8
15°C.	11·9	19·4	24·6	27·9
20°C.	5·9	7·5	20·3	25·6
Normal room temperature .	*nil*	3·2	15·3	21·1

TABLE VII

Readings after different hours at 30°C. taken on the average percentage of germination of micro-conidia after they were subjected to different temperatures for a period of nearly five months (21.3.1942 to 15.8.1942)

Constant temperatures to which spores were subjected	Average percentage after 8 hours	Average percentage after 10 hours	Average percentage after 12 hours	Average percentage after 15 hours
10°C.	17·0	21·5	26·5	31·8
15°C.	12·8	12·6	17·6	25·0
20°C.	*nil*	10·0	14·8	20·0
Normal room temperature .	,,	*nil*	*nil*	9·4

Tables V, VI, and VII show that the samples of micro-conidia kept at lower temperatures, retain their germination capacity better than those at higher temperatures. This fact is obvious from the comparative readings in any one of the tables. It is seen that the percentage of germination is the highest at the lowest temperature used and gradually decreases as the temperature, in which the conidia are stored, is increased.

The comparative studies of Tables V, VI and VII show that as the samples of micro-conidia are kept for a longer time at a particular temperature, the germination capacity of the spores is

reduced more and more. In the samples kept at the lowest temperature of 10°C. for a month the percentage of germination after 15 hours at 30°C. was 89·7 in April, this number decreasing to 31·8 in August after five months of storage. Similar was the case with the highest constant temperature used in this experiment. In the samples of micro-conidia stored at 20°C., the percentage of germination after 15 hours at 30°C. was 77·6 in April and 25·6 in July after four months of storage and 20·0 in August after five months of storage. These facts indicate that during a course of five months of storage at a particular temperature the germination capacity of micro-conidia is appreciably reduced and with the higher temperatures these changes become more marked.

Discussion

It is seen that in a pigeon-pea plant in an advanced stage of the wilt, the spores of *F. udum* can be found externally on the surface up to a height of five to six feet. The results of isolation experiments, as shown in Tables I and II, indicate that the external vertical distribution of the fungus, as judged by the presence of the spores on the plant surface, is always lower than the internal vertical distribution. This suggests that the superficial spores come after the fungus establishes and spreads inside the plant up to a certain height. This fact is further corroborated by the results obtained from the freshly wilted plant, where there are no superficial spores and the fungus is always present internally up to a certain height. Thus the idea that a spore, carried by air or water, germinates and that the fungus then spreads superficially on the aerial parts of the plants, is not supported by the evidence. Also, field observations show that this superficial sporulation of the fungus on the surface of the diseased plants comes late in the season, when the disease is fairly advanced.

Observations for two successive seasons in the pigeon-pea field of the Mycological Section at the Imperial Agricultural Research Institute, New Delhi, showed that in the following year the groups of diseased plants were found generally in the same spot where in the previous year one or more diseased plants were growing. These infested areas widened in diameter gradually from year to year. Therefore, in an infested field, diseased plants were found to lie always in patches, with a few stray plants attacked here and there. In subsequent years, in place of these stray plants, one would find two or more plants affected by the disease, depending on the rate at which the fungus had been able to grow in the meantime. This suggested that the stray diseased plants were the results of the current season's infestation, whereas the individuals in a group were the results of older infection.

In freshly wilted plants it is seen that a brown streak is present on the stem from the base of the plant upwards. The branches arising from these regions are those which wilt. The isolation studies, as seen from Table III, show that the fungus is present inside the vascular bundles in these blackened areas, whereas at the same height, but in other regions of the stem, the fungus cannot be traced. The facts suggest that in the beginning the fungus spreads inside and travels upwards in the regions of the vascular bundles and then spreads gradually to other portions of the stem. The branches coming in the path of advance of the fungus wilt one after another. This explains why, in a freshly wilted plant, there are some branches which are normal and healthy, whereas others are wilting.

Both laboratory and pot-culture experiments have shown that in pigeon-pea plants the wilt producing organism is not carried inside the seeds. The experiments in pots were continued up to a period of 16 weeks, the age at which Mundkur [1935] has shown that under filed conditions, in a plot which is not naturally infested but artificially made so, the maximum percentage of wilt is attained. Affording all possible favourable conditions, not a single case of wilt was observed in the pots, showing that the fungus is not borne inside the seeds.

Experiments have shown that the fungus has been able to reach the top internally, only in the plants that died early, and only in some of the branches of some of the dead plants. In some of the diseased plants which died early, although the fungus has spread internally to considerable heights of about six to seven feet, this has not been able to reach the top. In those freshly wilted plants, the internal spread of the fungus is only about two to three feet above the ground. These facts

show that the fungus can spread saprophytically inside the plants after their death, and, further that considerable time elapses between the death of the plant and the arrival of the fungus at the top. Thus, assuming the fact that the ability of the fungus to reach the top is a post-mortem phenomenon, the life continuity of the seeds with the plant is broken before the fungus reaches the seeds. Under these conditions, if the seeds are immature, they will not get time to mature and will simply harden up due to the loss of water in course of time. If the fungus can enter the pods before the seeds dry up, it can make its entry through the soft integuments into the seeds : but the seeds, immature as they are, will never be able to germinate. On the other hand, if the seeds are mature by the time of the plant's death, the hard integuments of seeds will make it difficult for the fungus to get inside. Therefore for infection of the seeds we must expect the following conditions: (1) The fungus should reach the seeds before the plants die ; (2) the seeds should be young and immature with their integuments soft so that the fungus can make an easy entry. Since the plants die before the fungus reaches the top and the organic connection of the seeds with the plant is severed with consequent discontinuity in seed nourishment, such conditions as outlined above probably never happen. Therefore, on purely theoretical grounds it seems that in the matured seeds which can germinate, the fungus cannot possibly be borne inside, even though it may be able to reach the top of the plants.

It was observed that about 50 per cent of the seeds collected from plants in an advanced state of the disease could not germinate and almost all the seeds from freshly wilted plants germinated normally. This seems to be due to the fact that in the plants which had died early, probably the seeds could not get time to mature properly, whereas in the freshly wilted plants, the seeds attained maturity before the disease could bring about the death of the plants. Therefore, the failure of some of the seeds collected from the diseased plants that died early, can rightly be ascribed to the immaturity of the seeds, and not to infection.

Furthermore, it was observed that the plants raised from the seeds of the diseased palnts that died early, were stunted in growth, less vigorous and sparsely branched ; but the seeds from the freshly wilted plants gave rise to normal plants. The difference between these two groups of plants was the attack of the disease at different stages of their growth. The loss of vigour, dwarfing effect and others which were noticed in this case were perhaps due to the discontinuation of certain processes in that chain of reactions which takes place for the proper nourishment of the embryo and thus affects the vitality of the seeds.

When debris from diseased plants carrying abundant micro-conidia on the surface, was stored at different temperatures, the micro-conidia retained their germination capacity better and for a longer time at low temperatures. As the temperature in which the samples of micro-conidia were stored was increased, the percentage of germination after any particular hour at 30°C. gradually became less. Also when the period of storage at any particular temperature was extended, the germination capacity of the micro conidia was gradually reduced. The germination of micro-conidia exposed to the normal room temperatures dropped appreciably after four to five months, though still a certain percentage of micro-conidia remained viable. The experiments were not carried far enough to determine whether under exposed conditions in the field spores may remain viable from one season to the next.

ACKNOWLEDGEMENT

Many thanks are due to Dr G. Watts Padwick, D.Sc., who suggested this problem to me and guided me in course of the work.

SUMMARY

(1) *Fusarium udum* Butler, which causes wilt of pigeon pea, forms abundant spore masses on the surface of infected plants.

(2) It was found that the spore masses occur only on branches of infected plants at a point considerably below that which the fungus has reached in the tissues, and it is concluded that the

spore masses do not form as a result of primary infection in the aerial parts, but arise as a result of the outward spread of the fungus from internally infected branches.

(3) The fungus was never found to be carried within the seeds.

(4) The conidia retain their viability for some months, but this falls off more quickly in normal room temperatures in summer months in Delhi than at a temperature of 20°C. or lower. It remains to be determined whether under field conditions they can survive from one crop season till the next

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PHYSIOLOGICAL STUDIES IN GROWTH AND DEVELOPMENT OF CROP PLANTS

I. PHOTOPERIODIC INDUCTION OF DEVELOPMENTAL ABNORMALITIES IN INDIAN WHEAT

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(Received for publication on 11 March 1946)

(With Plate XXIV and two text-figures)

FROM early days observations have been recorded on branching and other abnormalities of the reproductive spike in cereals and other plants. An excellent summary of earlier work has been given by Bose [1935] who observed branched heads in Indian barley and studied the inheritance of this character in F_2 and F_3 generations. Hurd-karrer [1933] made observations on the growth of normal winter and spring bread wheats when kept under short (8 hour) and long (17 hour) day at constant low (12°C.) and high (21°C.) temperatures. She found that at both low and high temperatures, short days produced long heads, the lengthening being most pronounced at the low temperature and mainly due to an increase in the distances between the lowermost spikelets. Under conditions of short days and low temperatures a secondary head was sometimes produced from the axil of the topmost leaf, and in Turkey, the winter wheat used, the main heads were often branched giving "miracle" bread wheats. Long days produced very short heads. In the winter wheat used, long days and the higher temperature often led to a failure to produce heads at all but resulted in the development of an elongated shoot with multiple vegetative branching at the nodes. Tumanyan [1934] has shown that forms with branched ears were only known in *Triticum turgidum* and *T. dicoccum* till lately. In 1929, however, he found some true soft wheats from eastern Anatolia with branched ears, which peculiarity was transmitted to the progeny. A new sub-species, called *Triticum vulgare compositum* was established for these branched wheats which are also characterized

by earliness, drought resistance, high percentage of protein in the grain and stiff straw. McKinney and Sando [1934] found that certain varieties of wheat grown under daily photo-periods of less than 13 hours or under continuous light of low intensity brought about twisting of the internodes at the base of the rachis in some of the tillers of a single plant. From the fact that not all varieties showed twisting under these conditions it was assumed that heritable factors were involved. The phenomenon of twisted trees has been considered by these workers in the light of the results on wheat. Biddulph [1935] working with plants of klondike variety of *Compositæ sulphureos* found that when they were transferred from short to long photo-periods several abnormalities developed including changes in the phyllotaxy, elongation and foliation of bracts, twin flower-heads and elongated internodes in the regions of the involucral bracts. Murneek [1940], on the other hand, demonstrated that Rudbeckia plants when transferred from long to 7-hour day either failed to flower or bore vegetative flowers, while some formed the usual type of flowers. By slowing down thermo-and photo-phases in wheat and rye, Zabluda [1940 and 1941] was able to produce abnormalities in spike structure, such as, the formation of true leaves at the base of the spike, conversion of spikelets into spikes and of spikelet scales into leaves. Recently Sharman [1944] obtained branched or normal heads of wheat in an F_1 progeny of a cross between a normal bearded bread wheat (*Triticum vulgare* Host, 2n=42) and a branched or 'miracle' headed Rivet wheat (*T. turgidum* L., 2n=28) by altering the time of sowing. This branching of ears was noticed only on the main stem. Tillers gave rise to normal heads in all cases. He concluded that the expression of this character was greatly influenced by the day-length and perhaps the temperature under which the plants were growing. He postulated that the branched-headed factor operated by altering the branched/normal-headed threshold and so could be made to behave as either a dominant or a recessive at will. As a result of extensive work on the interspecific crosses of wheat (*T. vulgare* x *T. vavilovianum* and *T. vulgare* x *T. spharococcum*), Pal and his associates at this Institute (unpublished work) have demonstrated that the compound spikelets of *T. vavilovianum* are inherited in the F_2 and F_3 generations and that the degree of compounding of spikelets in the crosses as well as in the species itself (*T. vavilovianum*) is greatly influenced by environmental and soil conditions.

It becomes clear from the above review that although some of these abnormalities may be genetic in nature they are in the main controlled by environmental factors, especially light and temperature. During the course of studies on photo-periodic responses of wheat at this Institute such abnormalities appeared in plants under certain photo-treatments. It was, therefore, decided to investigate the cause of these abnormalities, particularly with reference to their relation with the phasic development of wheat.

Experimental procedure

Graded seed of three pure line varieties of wheat (*Triticum vulgare* var. I.P. 165, I.P. 52 and P.C. 591) were germinated in Petri dishes, on a thin layer of sterilized sand.

Twenty-five seeds falling within a range of 45-50 mg. weight were placed in each Petri dish, watered with 5 ml. of distilled water and exposed immediately to the following photo-periodic treatments, (i) complete darkness, (ii) 6-hour daily illumination alternating with 18 hours of darkness, (iii) almost equal periods of light and darkness (normal day-light of October-March at Delhi), (iv) 18 hours of daily illumination alternating with 6 hours of darkness (normal day-light supplemented by artificial illumination from four 200 watt. day-light bulbs at a mean distance of 2 ft. from the seed for a requisite period). (v) continuous illumination (24-hour light period). After the completion of the above light treatments which have been called photo-inductive treatments, the seedlings were transplanted in unglazed pots and exposed to: (*a*) a short day (SD) with a 6-hour period of illumination, (*b*) normal day (ND) with almost equal periods of light and darkness, and (*c*) long-day (LD) either 18 hours or 24 hours of illumination as shown for different experiments. Full details regarding number of seedlings and pots used, growth measurements and length of different treatments are given separately for each experiment. Different combinations of photo-inductive and post photo-inductive treatments are described in the text by combining the serial number

of the former with the abbreviation of the latter. Thus for instance: 1-SD means that the seedlings were kept in complete darkness during the period of photo-inductive treatment and were subsequently exposed (post photo-inductive treatment) to a short day. 5-LD means that the seedlings received continuous illumination during the photo-inductive treatment and a long day during the period of post photo-inductive treatment and so on.

Experiment No. 1 (1941-42)

Varieties used. Three–I.P. 165, I.P. 52 and P.C. 591 (*T. vulgare*).

Photo-periodic treatments: 135 Petri dishes containing 25 graded seed (45-50 mg.) were moistened with 5 ml. of water and placed under the five photo-inductive treatments described above for the first 12 days. Thus 27 Petri dishes (nine for each of the three varieties) were placed under each treatment. The three post photo-inductive treatments already described were started immediately after the transplantation of seedlings in pots.

Growth observations

Mean period between the day of sowing and the day of first anthesis in 10 plants selected at random was taken as vegetative period for each treatment.

Number of spikelets and number of grains in the ears of five plants were counted and mean values per ear were obtained. Mean length of ear was also derived from observations on five plants. Results are presented in Table I.

It will be observed that the vegetative period is determined by the length of the day. Even the photo-inductive treatments which are of shorter duration compared to the post photo inductive treatments reduce the vegetative period. Number of spikelets and grain per ear as well as the length of the ear are all appreciably reduced in all combinations of photo-inductive treatment with subsequent long day (LD) in all the three varieties.

The above analysis (Table II) clearly reveals that both the photo-periodic treatments have a significant effect on ear development both as regards the number of spikelets as well as the length of ear. Although analysis of variance for the grain number as well as for the vegetative period have not been presented here, it has been carried out and in the case of the former it follows a parallel course with the number of spikelets per ear. LD treatment causes a reduction in number of spikelets ear length, grain number and vegetative period.

Experiment No. 2 (1942-43)

In order to confirm the results obtained in 1941-42, experiment No. 1 was repeated during 1942-43 with very few modifications.

Photo-periodic treatments

Only three photo-inductive treatments Nos. 1, 3, and 5 were used in this experiment. Duration of treatment was increased in each case to 14 days. SD and ND treatments were the same as in experiment No. 1. LD treatment was, however, continuous light instead of 18 hour day. In all 81 Petri dishes with 25 seeds in each were exposed to different photo-inductive treatments (27 each variety).

Growth observations were the same as in experiment No. 1. Ten plants were used for determining spikelet and grain numbers as well as the length of the ear.

TABLE 1

Development of the spike of three varieties of wheat under differential photo-periodic treatment (1941-42)

Photo-inductive and post photo-inductive treatment	Vegetative period (days)			Earliness over control (1—SD) (days)			No. of spikelets per ear			No. of grains per ear			Length of ear (cm.)			Abnormalities, if any
	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	
1—SD . .	99·1	105·2	113·7	.	.	..	14·0	15·0	16·0	7·9	21·2	4·0	7·2	6·4	6·2	Normal ears
2—SD . .	98·7	102·2	113·0	0·4	8·0	0·7	15·2	17·0	18·2	13·8	19·6	16·8	7·0	6·9	7·2	Ditto
3—SD . .	98·5	97·8	108·2	0·6	7·4	5·5	17·0	19·0	19·0	14·6	20·6	17·0	8·8	7·4	8·2	Ditto
4—SD . .	96·4	97·3	107·2	2·7	7·9	6·5	16·0	15·8	19·8	15·9	13·3	..	7·9	6·2	7·9	Ditto
5—SD . .	87·5	93·3	105·4	11·6	11·9	8·3	16·0	15·4	18·2	16·2	9·5	9·5	8·8	6·0	7·1	Rachis between 1st and 2nd spikelets of main ear elongated
1—ND . .	81·6	87·7	96·4	17·5	17·5	17·3	16·6	17·8	15·8	24·8	31·0	23·0	9·5	7·2	7·4	Normal ears
2—ND . .	78·1	84·0	95·8	21·0	21·2	17·9	16·4	19·0	17·0	28·4	29·9	27·6	9·2	7·3	8·0	Ditto
3—ND . .	70·9	79·5	89·3	28·2	25·7	24·1	19·4	19·4	16·8	28·3	30·8	25·6	10·1	7·5	8·3	Ditto
4—ND . .	70·0	77·7	84·8	29·1	27·5	28·9	19·0	19·8	19·0	28·5	32·8	..	9·5	7·9	9·1	Rachis elongated in I.P. 52 and P.C. 591
5—ND . .	66·7	67·8	78·9	32·4	37·4	34·8	18·6	17·0	20·2	23·1	21·2	28·3	8·8	5·9	8·2	Rachis elongated in all varieties. Branched main ear in I.P. 52. Compound spikelets in P.C. 591
1—LD . .	61·2	60·5	65·2	37·9	44·7	48·5	12·6	14·2	14·6	6·6	4·1	5·1	6·3	5·0	6·3	Short ears
2—LD . .	56·0	57·1	65·3	43·1	48·1	48·4	13·4	13·8	13·4	8·9	5·3	10·0	6·8	5·7	6·7	Ditto
3—LD . .	54·5	55·7	63·9	44·6	49·5	49·8	15·0	13·8	15·4	8·1	8·5	9·2	8·0	5·8	7·0	Ditto
4—LD . .	53·7	54·8	..	45·4	50·4	..	15·8	15·4	14·4	6·6	7·5	..	8·6	5·4	7·5	Ditto
5—LD . .	50·0	50·4	54·9	49·1	54·8	58·8	17·0	13·4	16·2	6·4	9·3	8·3	7·5	5·4	7·0	Ditto

TABLE II

Analysis of variance of spikelet number and ear length (Table I)

No.	Treatment	Degrees of freedom		Sum of squares		Mean square		Treatment variance / Error variance	
		Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length
1	Replicates	4	4	7·9	0·54	1·98	0·14	1·4	0·5
2	Post photo-inductive treatment	2	2	484·6	105·18	242·30	52·59	177·1 S	194·0 S
3	Photo-inductive treatment	4	4	145·4	36·00	36·35	9·00	26·5 S	33·3 S
4	Varieties	2	2	25·0	132·49	12·50	66·24	9·1 S	245·0 S
5	Interaction : 2×3	8	8	48·2	11·87	6·03	1·48	4·4 S	5·4 S
6	Interaction : 2×4	4	4	80·4	7·77	20·20	1·94	147 S	7·2 S
7	Interaction : 3×4	8	8	83·2	16·54	10·40	2·07	7·6 S	7·6 S
8	Interaction : 2×3×4	16	16	68·6	14·37	4·30	0·90	3·1 S	3·3 S
9	Error	176	176	240·9	47·86	1·37	0·27		
	TOTAL	224	224	1184·2	372·62	..			..

S denotes highly significant effects of treatments and interactions (P.LO·01).

TABLE III

Development of the spike of three varieties of wheat under differential photo-periodic treatment (1942-43)

Photo-inductive and post photo-inductive treatment	Vegetative period (days)			Earliness over control (1—SD) (days)			No. of spikelets per ear			No. of grains per ear			Length of ear (cm.)			Abnormalities, if any
	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	I.P. 165	I.P. 52	P.C. 591	
1 SD	116·7	118·5	134·6	..	..	..	15·7	12·6	9·9	28·2	14·0	6·5	6·4	4·5	3·7	Normal ears
3 SD	107·5	99·1	111·0	9·2	19·4	23·6	16·0	16·4	14·7	31·1	20·1	22·4	9·5	6·0	7·1	Ditto
5 SD	104·9	95·8	101·6	11·8	22·7	33·0	16·4	13·6	14·6	31·3	21·6	24·1	9·5	5·7	5·9	Rachis between 1st and 2nd spikelets of [illegible] ear elongated
1 ND	87·5	93·1	100·3	29·2	25·4	34·3	16·1	17·1	15·2	30·8	34·1	30·0	9·4	6·9	6·9	Normal ears
3 ND	84·8	89·8	95·4	31·9	28·7	39·2	16·1	17·7	16·0	29·4	40·2	30·5	9·3	7·1	7·6	Ditto
5 ND	79·1	81·7	85·4	37·6	36·8	49·2	15·1	17·5	17·7	26·1	36·0	28·1	8·6	7·0	7·7	Rachis elongated. Compound spikelets in P.C. 591. Branched ear in I.P. 52
1 LD	78·0	77·6	74·7	38·7	40·9	59·9	8·5	8·0	8·9	9·1	10·6	14·9	6·3	4·5	5·5	Short ears
3 LD	62·2	67·2	66·5	54·5	51·3	68·1	11·4	9·8	10·7	6·6	9·6	13·4	6·3	4·8	5·6	Ditto
5 LD	60·8	63·0	67·0	55·9	55·5	67·6	8·6	9·9	10·5	9·2	13·1	15·2	5·8	4·4	5·3	Ditto

FIG. 1. Branching of ears in I P 52 wheat under photoperiodic treatment ; A, ear from 5-LD treatment, B, ear from 5-ND treatment (Experiment No. 1) and C, ear from 5-ND treatment (Experiment No. 2)

TABLE IV

Analysis of variance of spikelet number and ear length (Table III)

No.	Treatment	Degrees of freedom		Sum of squares		Mean square		Treatment variance / Error variance	
		Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length	Spikelet No.	Ear length
1	Replicates	9	9	58·96	19·13	6·55	2·12	0·68	1·9
2	Post photo-inductive treatment	2	2	2283·12	272·66	1141·56	136·33	118·40 S	126·0 S
3	Photo-inductive treatment	2	2	170·76	48·77	85·38	24·38	8·80 S	22·5 S
4	Varieties	2	2	21·45	249·32	10·72	124·66	1·10	115·4 S
5	Interaction: 2 × 3	4	4	47·66	75·55	11·91	18·89	1·20	17·5 S
6	Interaction: 2 × 4	4	4	162·24	39·66	40·56	9·91	4·20 S	9·1 S
7	Interaction: 3 × 4	4	4	71·33	3·92	17·83	0·98	1·80	0·9
8	Interaction: 2 × 3 × 4	8	8	81·05	20·77	10·13	2·59	1·05	2·4
9	Error	234	234	2256·84	254·33	9·64	1·08		
	TOTAL	269	269						

S denotes highly significant effects of treatments and interactions (P < 0·01).

Results of this experiment (Table III) fully corroborate the findings of the previous year (Table I) in that the post photo-inductive treatment LD in combination with all the three photo-inductive treatments causes a highly significant reduction in the spikelet and grain numbers as well as in the length of the ear. Other abnormalities which will be described presently are also reproduced especially when the plants are transferred from a long photo-period (Treatment No. 5) to post photo inductive treatments with shorter photo-periods (SD and ND).

Experiment No. 3 (1942-43)

The occurrence of branching of main axis and other abnormalities in plants under 5 SD and 5-ND treatments (Table I and Plate XXIV, fig. 1) and absence of these abnormalities under other light treatments gave an indication of the existence of a critical state in the formation of reproductive primordia. This result has been subsequently confirmed by results of experiment No. 2. Experiment No. 3 was designed to determine the length of the photo-inductive treatment (No. 5) necessary for causing a significant change in the development of the spike.

Variety. Only one variety I.P. 52 wheat which gave very good response to light treatments was selected for this work.

Photo-periodic treatment : Germinating seeds (in 42 Petri dishes) were kept under continuous illumination for varying number of days ranging from one day to the whole growth period. There were in all 14 treatments as indicated in the first column of Table V. After the completion of each photo-inductive period the plants were transferred to normal day illumination for the rest of their growth period.

Growth observations were the same as in experiment No. 1.

TABLE V

Critical photo-inductive period causing reduction in spikelet and grain number as well as in ear length (1942-43)

Photo periodic treatment	Vegetative period (days)	Earliness over control (days)	No. of spikelets per ear	No. of grains per ear	Length of ear (cm.)	Abnormalities, if any
All normal days	91·7	..	19·0	46·0	7·2	Normal ears
1. Long day and than N.D.	89·4	2·3	18·5	44·7	7·3	Ditto.
2. Long days Ditto	87·3	4·4	18·3	43·6	8·1	Ditto.
3. Ditto	87·6	4·1	18·5	43·9	7·5	Ditto.
4. Ditto	93·6	1·9	18·8	42·6	7·2	Ditto.
5. Ditto	88·1	3·6	19·6	46·1	7·4	Ditto.
6. Ditto	88·3	3·4	19·1	43·6	7·2	Ditto.
7. Ditto	86·0	5·7	18·3	43·6	6·6	Ears slightly shorter
8. Ditto	84·0	7·7	18·8	43·4	6·7	Ditto.
9. Ditto	84·6	7·1	18·6	42·8	6·5	Ears short Rachis elongated
10. Ditto	82·8	8·9	17·4	42·3	6·3	Ears short Rachis elongated
13. Ditto	81·9	9·8	16·9	39·9	6·2	Main ears very short Rachis markedly elongated Branching of main ears
20. Ditto	78·1	13·6	14·6	28·1	5·8	Main ears very short Rachis markedly elongated No. of spikelets in the main ear reduced to 4-5 Branching of main ears
All long days	63·0	28·7	9·8	13·4	4·3	Ears very small but without any abnormalities like branching

The ears become shorter in photo-inductive treatment with seven long days, and progressively become shorter and shorter as the photo-inductive treatment is prolonged. Reduction in numbers of spikelets and grains is, however, noticeable in the photo-inductive treatment with 10 or more days of continuous illumination. It would be well to remember here that figures for the number of spikelet and grain are average of all the ears of 10 plants. If only the main ear is considered there is a far greater reduction in spikelet and grain number than shown in the tables of results given here.

Branching of ears and other abnormalities

Over and above the shortening of ears and reduction in the number of spikelets and grains certain other abnormalities have been observed which are described in the last columns of Tables I, III, and V as well as shown in Figures 1, and 2.

When I.P. 52 plants are transferred from No. 5 (24 hour-day) photo-inductive treatment to SD (6 hour-day) treatment the rachis between the 1st and 2nd spikelets (counting from the base) gets elongated. Branched ears are obtained in the same variety if the plants are transferred from No. 5 photo-inductive treatment to normal day. When the plants of the same variety are continuously kept under long day conditions (as in 5-LD treatment) no abnormality in spike development other than the shortening of the ear and the reduction in the number of spikelets and grains occurs. The abnormalities in the development of the spike of I.P. 52 wheat under different photo-periodic treatments are shown in Plate XXIV. On the left hand side an ear (A) from 5-LD treatment is shown which is characterized by reduction in the number of spikelets and the ear length. In the centre a branched ear (B) from 5-ND treatment of experiment No. 1 is shown. On the right hand side a branched ear (C) of the same variety observed in 5-ND treatments of experiment Nos. 2 and 3 is shown. An interesting feature of the branched ear (C) for 1942-43 is that two vegetative branches have been given out (Plate XXIV, fig. 1-C).

In the case of I.P. 165, abnormalities were least noticeable. Except for the elongation of rachis between the first and the second spikelet under 5-SD and 5-ND treatments (Tables I and III), which was sometimes quite pronounced, no other abnormality was noticed.

In P.C. 591, over and above the usual elongation of rachis between the first and the second spikelet under 5-SD and 5-ND treatments (Tables I and III) compound spikelets appeared under 5-ND treatment (Fig. 1).

FIG. 1.

FIG. 2.

It is worthy of note that in all these cases such abnormalities were observed only in the spike of the main shoot. All the ears developing from the tillers of the same plant were apparently normal although there was a reduction in their size and also in the number of spikelets and grain.

In experiment No. 3 abnormalities such as branching of ears on the main stem began to appear only when the photo-inductive period of continuous illumination was longer than 10 days. In experiment Nos. 1 and 2 in which branching of ears was also observed, the photo-inductive periods of continuous light was of 12 and 14 days respectively. In other words the presence of a threshold light value is indicated for the production of such abnormalities. A few plants from all the treatments (of experiment No. 3) were dissected out at the shooting stage for studying the growth of the spike. No abnormalities were observed in any treatment except in plants which had received 15 and 20 days of continuous illumination as photo-inductive treatment, where a number of primordia

(2 to 4) appeared at the base of the main ear-head. A diagramatic representation of this abnormality is given in Fig. 2 which is drawn on a magnified scale (x 10) to make the growing points visible.

General discussion

As already stated in the introductory part of this paper, abnormalities generally appear as a result of changes in environmental conditions, especially photo-periodic in nature [Biddulph, 1935; Murneek, 1940; Zabluda, 1940-41; Hurd-karrer, 1933; Sharman, 1944; and McKinney and Sando, 1934]. In the present investigation as well as in a previous communication by Nanda and Chinoy [1945], abnormalities have been observed when the photo-periodic treatment was changed from continuous illumination to a subsequent short or a normal day (5-SD and 5-ND tratments of Tables I and III and photo inductive treatment of 15 to 20 days of continuous illumination in Table V).

The above evidence suggests a causal connection between the phasic development of wheat and these abnormalities. According to Lysenko (*Imp. Bur. Pl. Genet. Bull.* No. 17, 1935) "the qualitative changes occurring in the cells of the embryo at the time of vernalization constitute some permanent change of state which is transmitted to all later generations of cells throughout the life of the plant". Ljubimenko (quoted from *I.B.P.G. Bull.* No. 17) differing from Lysenko in his interpretation of the change occurring during vernalization has given considerable amount of evidence to demonstrate the impermanent and reversible nature of thermal and photo-periodic induction effects which are comparable to Lysenko's vernalization effects. Litvinov, Konstantinov, Bassarskaja, Gavrilova, Capikova and Zerling and Novikov (*Imp. Bur. Pl. Genet. Bull.* No. 17, 1935, pp. 39, 40, 47, 49, 79, and 82) and Gregory and Purvis [1938] have demonstrated the reversibility of changes occurring during vernalization. It, therefore, appears that there is a critical phase in the development of a young cell when it can be moulded into a vegetative or a reproductive organ depending upon the stage to which the qualitative change has proceeded in the cell during the induction period.

Evidence presented here (5-LD treatment of Tables I and III and the last treatment—all long days—of Table V) clearly demonstrates that the induction treatment when carried beyond a certain stage would affect a permanent change in all the later generations of cells. No abnormality such as branching of ears or elongation of rachis is, therefore, noticeable in such treatments. The reversible nature of the qualitative change, however, becomes apparent when the plants are transferred from long to a comparatively shorter photo-period, as in 5-SD and 5-ND treatments as well as in a photo inductive treatment of 15 to 20 days of continuous illumination (Table V). Here branching of the main ear is observed, whereas all other ears arising from tillers are structurally normal. It can, therefore, be assumed that the induction effect has not been fully transmitted to all later generations of cells, as maintained by Lysenko. Neither Lysenko's concept of irreversibility of vernalization nor Ljubimenko's idea of the reversibility of induction effect can satisfactorily explain these evident disturbances in the symmetry of growth and development of a plant. The concept of hormonal regulation of growth and development is now generally recognized [Cholodny, 1939, and Gregory and his associate, 1937 and 1938].

The nature of the qualitative change under discussion here can, therefore, be explained by postulating that a change in the photo periodic treatment brings about an alteration in the rates of production and of utilization of the regulatory substance, thus affecting its concentration in the growing points. Such a change in the concentration of the regulatory substance is likely to cause disturbances in growth and developmental symmetry of a plant. The response obviously will vary with the genetic constitution.

Summary

1. Photo-inductive and post photo-inductive treatments were given to three varieties of wheat (*T. vulgare*), I.P. 165, I.P. 52 and P.C. 591 for varying periods and the influence of these treatments on vegetative period, number of spikelets and grains per ear, as well as its length were recorded.

2. Under long-day conditions (5-LD) number of spikelets and grain and the length of the ear were considerably reduced. There were no other structural abnormalities under continuous long-day treatment.

3. If, however, the plants were transferred from a long day to a short or a normal day, different types of abnormalities, such as, branching of ear (Fig. 1), elongation of rachis (Tables I, III, V) and compounding of lowermost spikelets (Fig. 2) made their appearance.

4. The presence of a threshold light value for the production of such abnormalities is indicated by the fact that a photo-inductive period of 12 to 20 days of continuous illumination is necessary for producing them.

5. It is postulated that such disturbances in the symmetry of growth and development are brought about by changes in the concentration of regulatory substances in growing points under the influence of an altered photo-period, differential response being given by different genotypes.

ACKNOWLEDGEMENT

We are indebted to Dr B. P. Pal, Imperial Economic Botanist, for reading the manuscript and for his valuable criticism.

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CRYPTOSTEGIA GRANDIFLORA R. BR., A WAR TIME SOURCE OF VEGETABLE RUBBER

VI. YIELD OF LATEX AND RUBBER

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(Received for publication on 8 December 1945)

(With Plates XXV and XXVI)

THE detailed investigations on *Cryptostegia grandiflora* were undertaken at the instance of the Department of Supply. A search of the literature showed that Jumelle [1913] had found 2 per cent of rubber of inferior quality while Dolley [1925, 1927] discussed the commercial possibilities of the plant and described the results of analysis of a sample of rubber. Polhamus [1934] mentioned the rubber content of leaves of the four species while analytical data of solid rubber and vulcanisation tests were given by Trumbull [1942]. This little information gave no guidance for the formulation or development of methods for the production of rubber from the plant.

A plan for obtaining rubber by direct and indirect methods was prepared. The former consisted of a tapping programme while the latter included production of rubber by mechanical extraction or bacterial decomposition or fermentation of the *Cryptostegia* material. The results obtained under the latter were embodied in Parts III and V of this series while those of the former were described partly in Parts I and II and are partly given in this investigation as well.

Tapping or method for the collection of latex from laticiferous plants is very old. 'Of the various methods of tapping rubber trees, that which with a similar amount of work, yields the greatest amount of good rubber over a longer period of time and which damages the tree the least (so that plantation will remain productive the greatest possible length of time) is in general to be designated as the most rational' [1934]. In *Hevea* the latex used to be drawn by the herring bone, the repeated 'V' and the spiral cuts, but now these methods have been abondoned and the form of cut most generally used consists of a horizontal or inclined cut from left to right in the bark and the latex slowly oozes out and trickles down into a cup placed below (Plate XXVI, figs. 1 and 2). In the case of *Cryptostegia* the bark tapping method is not possible owing to the small girth of an irregular and corrugated trunk of even 30-40 years old plants and also to the fact that on injuring the bark of the trunk only very tiny dropets of latex come out and the flow of latex occurs at active centres of growth (Plate XXV, figs. 1 and 2) show *Hevea* trees and *Cryptostegia* shrubs.

A microscopic study of laticiferous plants has revealed that the latex occurs in cells, tubes and vessels. The cells are not interconnected and the latex flows from them when they are opened by a cut and so plants with cells cannot be tapped like those provided with tubes and vessels. In plants with tubes and vessels the laticiferous system forms a net work of channels which run through the body of the plant and yield a large quantity of latex when cut. A study of longitudinal sections of *Cryptostegia* and *Hevea* (Plate XXV, figs. 3 and 4) revealed that in the latter the latex vessels which form a net work of channels are confined mostly to the outer and inner bark of the stem while in the former they are branched and are distributed in the cortex in the secondary phloem and in the pith. There are relatively more cells in the pith than in the bark and therefore tapping is best done by the clipping of the branches rather than incising the bark as in the case of *Hevea*.

Every part of *Cryptostegia* yields latex but its flow is more from tender twigs of the size of an ordinary pencil than from the old ones, pods, leaves, or trunk. On bleeding a tender whip the latex drips for about two minutes yielding 6-12 drops for the first cut (5-6 drops in old twigs and green seed pods) but further four cuts in succession gave 4, 4, 2 and 1 drop respectively (old twigs none, seed pods 2 and 1). Subsequent clipping gave no more drops due to the thickening of latex and its coagulation at the cut end. This coagulated latex after drying forms a plug. When the plug is pulled out a drop or two of latex oozes out but better flow occurs when a bit about an inch is nipped off. It was also observed that from the growing point of a whip at a height of 27 ft. of a four years old plant which had the support of a wall only 2 drops of latex were obtained in two minutes and a half and none on subsequent clipping of the same whip.

For the collection of latex 3 or 4 twigs are clipped off by a pruning scissors. They are thrust into the mouth of the test tube and latex collects in it (Plate XXVI, fig. 3). Bamboo tubes six inches in length with an internal bore of one inch were later substituted for glass tubes (Plate XXVI, fig. 4) which even if it were possible to avoid breakages, become too hot in summer and too cold in winter. They are easy to handle and non breakable but the difficulty of cleaning them may be considered a defect. Further they are liable to split with changes in temperature and humidity, but that can be prevented by binding them with wire.

Employing the foregoing technique experiments were undertaken to ascertain (*a*) the best part of the day suitable for tapping, (*b*) effect of tapping on regeneration and growth of shoots, (*c*) the effect of frequency of tapping, and (*d*) seasonal variations affecting the yield of latex. The following conclusions were drawn:

(*a*) *The best part of the day suitable for tapping.* When different bushes are tapped either daily or on alternative days, the yields of both latex and rubber are more from the afternoon than from the morning tappings. If, however, the same bushes are continuously tapped even on alternate days, the yields are more from the morning tappings.

FIG. 1. *Hevea* trees—normal source of rubber

FIG. 2. *Cryptostegia*-shrubs, emergency source of rubber

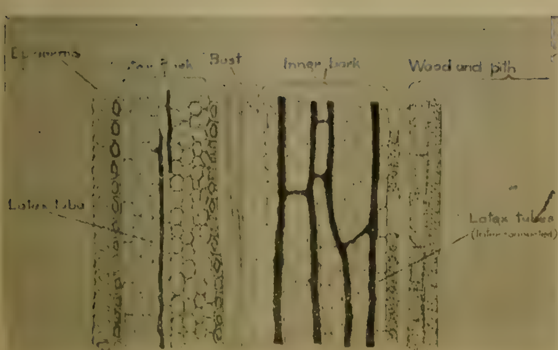

FIG. 3. Latex-bearing vessels of *Cryptostegia*

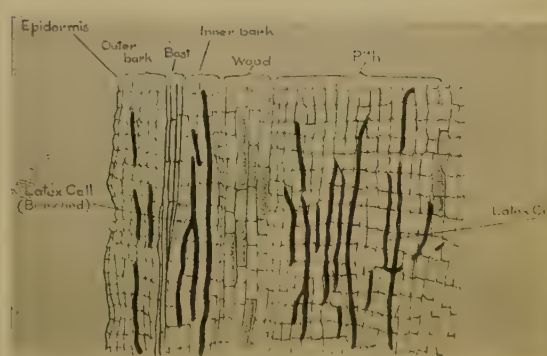

FIG. 4. Latex-bearing vessels of *Hevea*

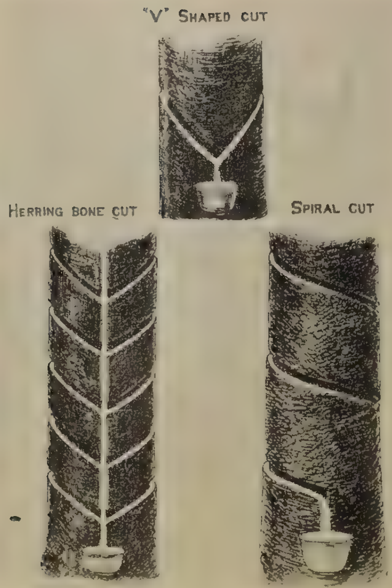

FIG. 1. Tapping of latex in *Hevea* by V-shaped, herring-bone and spiral cuts

FIG. 2. Tapping of latex in *Hevea* (in cups)

FIG. 3. Tapping of latex in *Cryptostegia* in glass tubes

FIG. 4. Tapping of latex in *Cryptostegia* in bamboo tubes

(*b*) *Effect of tapping on regeneration and growth of shoots.* The experiments conducted by the Botany Division of this Institute revealed that under any system of tapping regeneration is quick and that there is no serious adverse effect on regeneration although the tendency is for the untapped runner to develop more sprouts than the tapped one. Further, of plants pruned at 6 in., 9 in., 12 in. and 24 in. levels above the ground, those pruned at the 12 in. level are better as regards regrowth and the number of the whips formed and pruning away non-whip branches does not show any advantage so far as growth of whips is concerned. The pruning of whips (when they attain a reasonable stage of maturity) at about 6 nodes from their origin give a larger number of whips for plants than the unpruned controls.

(*c*) *Effect of frequency of tapping on the yield of latex and rubber.* The third system of tapping is economical from view points of yield, labour and strain to the plant.

(*d*) *Seasonal variations affecting the yield of latex.* The plantation of *Cryptostegia* at Okhla (Delhi) was divided into a number of blocks and the work was done under the supervision of the Rubber Directorate of the Supply Department.

Mixed tapping programme (alternate and third day) was started of blocks 1 and 12 on the 22nd April, 1943, and was continued till 17th July and on the following day purely alternate daily tapping was started of fresh blocks 2 and 10 which was continued till about the middle of June, 1944. In March 1944, two more blocks (12 new, 1 new) were brought under this tapping. On the other hand, third daily tapping of blocks 3 and 4, 5 and 6 and 9 and 11 commenced in the second week of November, 1943, and in April, 1944 was supplemented by blocks A, B and C. Thus the two systems of tapping was commenced in a number of blocks in different seasons of the year with a view to finding out the effects of seasonal variations and other physical factors on the yield of latex, rubber, and plugs.

For seasonal changes the following dates have been assumed. Summer 15th April-14th June, rainy season 15th June-14th August, autumn 15th August-14th October, winter 15th October-14th February and spring 15th February-14th April. If only two seasons, summer and winter are reckoned in one year the former would range from 15th April to 14th October and the latter from 15th October to 14th April. The average yield of blocks for one month of the two systems, during various seasons are given in Table I.

The averages of tapping data in Tables I and II are calculated from the observations recorded at Okhla by Capt E. P. Hosken while dry rubber content (D. R. C.) percentages were determined in the Chemistry Division of the Imperial Agricultural Research Institute.

TABLE I

Average yield for one month per 1000 shoots of Cryptostegia

Average yield for one month during	Yield per 1000 shoots			D.R.C.	Name of block	System of tapping
	Latex	Rubber	Plugs			
Full summer including rainy season and autumn (15th April to 14th October).	128·4	5·6	11·3	4·4	1 and 12 2 and 10	Mixed alternate daily
Full winter including spring (15th October—14th April).	191·2	15·4	9·8	8·1	2 and 10	Alternate daily
Ditto	149·4	12·6	6·2	8·5	3, 4, 5, 6, 9 and 11	Third daily
Summer (15th April—14th June)	127·9	6·9	14·3	5·4	2 and 10	Alternate daily
Ditto	119·9	4·5	26·9	3·8	1 and 12 new	Ditto
Ditto	123·9	8·3	7·1	6·7	3 and 4, 5 and 6, 9 and 11	Ditto Third daily
Ditto	102·3	5·3	18·3	5·2	A, B, C	Ditto
Rainy season (15th June—14th August)	116·3	3·4	9·9	2·9	2 and 10	Alternate daily
Autumn (15th August—14th October)	141·7	6·8	9·9	4·8	2 and 10	Ditto
Winter (15th October—14th February)	192·4	14·7	8·3	7·6	2 and 10	Ditto
Ditto	142·3	11·4	4·8	8·0	3 and 4, 5 and 6, 9 and 11	Ditto Third daily
Spring (15th October—14th February)	188·7	16·8	12·6	8·9	2 and 10	Alternate daily
Ditto	203·3	9·3	32·8	4·6	..	
Ditto	163·4	14·9	8·7	9·1	3 and 4, 5 and 6, 9 and 11	Ditto Third daily

From the foregoing statement it would appear that winter months are better producers of latex and rubber than the summer and in winter the spring shows the maximum yield. The rainy season gives a diluted latex with a minimum D. R. C. while the yield during summer and autumn months remains more or less uniform. For the formation of plugs, however, summer should be regarded as the best season. The third daily tapping is preferable to the alternate daily from the view points of better yield of rubber from latex and more rest to the plant and if a successful tapping programme is to be started it should be carried out during winter months which could be extended further, but the rainy season should always be excluded to avoid low yield and unnecessary labour.

Summer and winter monsoon. The effect of dilution on latex is more perceptible during summer monsoon than in the winter monsoon because in the latter case it consists of a couple of light showers during cold months which are not enough to change the normal course of the yield of latex, etc.

Wind. The velocity of wind and its direction do not appear to have any effect on the yield of latex and rubber.

Humidity. No generalizations can be put forward with regard to humidity in relation to the yield of latex, etc. During July, August and September, humidity variations of 100-39, 91-70, 98-50 (monthly averages– 77, 82·9 and 84·9) respectively were observed and the latex had a poor rubber content (3·89, 3·23, 3·54 respectively), while in January, February and March there were the same fluctuations of humidity 100-54, 100-48, and 91-33 (monthly average of 77·9, 72·1 and 63·6 respectively), but the latex had a fairly high D. R. C. (8·15, 8·24, 8·41 respectively). It may be said, however, that humidity ranging between 30-60 during winter months along with low temperatures, exercises a certain effect on the production of latex in the plant while a still low humidity of summer months is helpful in the formation and drying of plugs.

Temperature. In Table II are given the average maximum temperatures for the months and the yields of latex, etc. The results show that during summer as the temperature increases the D. R. C. decreases and with a decrease of temperature especially during winter months there is a gradual increase of D. R. C. Thus high temperature decreases the formation of rubber in latex while a fall in temperatures raises it. On the other hand, the yield of rubber from plugs increases with an increase in temperature and decreases as it falls. On account of these reasons an equal quantity of rubber (rubber from latex and rubber from plugs) is produced both in the winter and in summer. If winter favours the tapping programme the summer equally advocates the collection of plugs.

Periods of defoliation and refoliation, flowering and fruiting. In general, defoliation starts towards the second or third week of January and is practically complete by the end of February. Soon after defoliation or almost simultaneously with it, small pinkish leaves and sprouts make their appearance and thereafter the growth is fairly rapid. It may incidentally be mentioned that at Okhla plantations of the bushes towards the canal bank started defoliotions and refoliations later than those away from it and in the Botanical Division of this Institute it was observed that plants in a plot which had received considerable manuring and had, in consequence, put up a more luxuriant growth defoliated much later and less severely than those in the other plots where the plants were poor in growth owing to a lesser degree of manuring. By the middle of April, the plants started flowering, but this flush did not result in setting up of follicles. Next flowering commenced during October and November and this time follicles did set which attained maturity by middle of March. The results of Table I show that the yield of latex and rubber, etc. is much more during the winter months than in the summer and goes on increasing with the commencement of winter till the close of the spring (15th October-14th April) and declines thereafter. Thus the periods of defoliation and refoliation, flowering and fruiting appear to have effect on the yield of latex, etc.

Yield of latex, rubber and plugs per acre per annum. The statement given in Table III is indicative of the yield of latex and rubber per acre per annum for alternate and third daily tappings. The total rubber obtained from the two systems is 138·9 and 113·3 lb. respectively (from latex alone 69·9 and 69·1 lb. respectively) for 10,000 bushes each with 25 tapable branches. The number of shoots vary according to the size and age of the plant, but 25 appears to be a reasonable average number. In one year old plants, however, 6-10 shoots will be available for tapping and the yield

should not be expected to exceed one quarter of that given above per acre per annum. The present investigation includes observations for one year and is indicative as to the probable variations in the yield of latex and rubber. No final conclusion can be drawn at this stage about the yield of rubber per acre and the reaction of the plant with regard to tapping and to decide this, it is necessary to have at least five years data of the various tapping systems in different climatic conditions and in different localities of India. In view of the present observations about the yield of rubber from *Cryptostegia* the conclusion arrived at and reported earlier [1943] appears to be misleading.

TABLE II

Average maximum temperature and the yield

Month	Average max. temp.	Average humidity	In gm. on 1,000 shoots			D.R.C.	Name of block	System of tapping
			Latex	Rubber	Plugs			
22nd April to 30th April, 1943.	87·7	33·3	93·5	7·2	11·8	8·0	1 and 12	Mixed
May 1943	105·6	24·4	272·5	11·5	27·5	4·2	1 and 12	Ditto
June 1943	102·6	45·4	175·1	6·5	19·1	3·8	1 and 12	Ditto
July 1st—18th.	..	..	139·8	3·3	13·5	3·2	1 and 12	Ditto
July 21st—31st	93·9	77·0	109·7	2·9	7·4	3·2	2 and 10	Alternate daily
August	90·0	82·9	256·6	7·8	18·6	3·5	2 and 10	Ditto
September	92·8	84·5	285·2	13·4	20·2	5·2	2 and 10	Ditto
October	94·0	44·0	328·2	19·1	20·2	6·4	2 and 10	Ditto
November	85·7	44·1	306·1	30·5	17·3	6·9	2 and 10	Ditto
November	85·7	44·1	300·1	22·9	8·8	7·9	3 and 4, 5 and 6, 9 and 11	Third daily
December	77·3	62·8	372·1	29·1	10·1	8·2	2 and 10	Alternate daily
December	77·3	62·8	461·1	26·9	18·1	8·7	3 and 4, 5 and 6, 9 and 11	Third daily
January	68·7	77·8	462·9	37·9	16·0	8·2	2 and 10	Alternate daily
January	68·7	77·8	526·2	42·9	18·8	8·6	3 and 4, 5 and 6, 9 and 11	Third daily
February	74·4	72·1	437·7	35·9	22·0	8·4	2 and 10	Alternate daily
February	74·4	72·1	526·2	42·9	18·8	8·6	3 and 4, 5 and 6, 9 and 11	Third daily
March	80·3	63·6	347·6	34·7	24·3	10·4	2 and 10	Alternate daily
March	80·3	63·6	499·4	48·9	24·9	10·7	3 and 4, 5 and 6, 9 and 11	Third daily
April	94·8	46·9	358·7	30·8	35·7	9·2	2 and 10	Alternate daily
April	94·8	46·9	439·9	37·5	32·4	8·8	3 and 4, 5 and 6, 9 and 11	Third daily
May	108	27·0	511·6	30·0	27·4	6·1	2 and 10	Alternate daily
May	108	27·0	641·0	41·8	33·1	6·6	3 and 4, 5 and 6, 9 and 11	Third daily

TABLE III

Yield of latex, rubber and plugs per acre

Period	Alternate daily			Third daily		
	Latex	Rubber	Plug	Latex	Rubber	Plug
		(In gm.)			(In gm.)	
Average yield for 1 month for 1,000 plants with 1 tapable shoot during summer	128·4	5·61	11·3	123·9	8·30	7·07
Yield for six months for 1,000 plants with 1 tapable shoot during summer	770·4	33·66	67·8	743·4	49·8	42·42
Yield for six months for 10,000 plants with 1 tapable shoot during summer	770·4	336·60	678·0	7434	498	424·20
Yield for six months of 10,000 plants with 25 tapable shoots during summer per acre	192600	8415	1695	185850	12450	10605
Yield of latex, rubber and plugs for six months during summer (in lb.)	424·6	18·5	37·3	409·7	27·1	23·3
Total yield of latex and rubber for six months per acre (in lb.)	424·6	55·8	409·7	50.7	..	..
Average yield for 1 month for 1,000 plants with 1 tapable shoot during winter	191·2	15·4	9·75	149·4	12·6	6·2
Yield for six months for 1,000 plants with 1 tapable shoot during winter	1147·2	92·4	58·50	896·4	75·6	37·2
Yield for six months for 10,000 plants with 1 tapable shoot during winter	11472	924	585	8964	756	372
Yield for six months for 10,000 plants with 25 tapable shoot during winter per acre	286800 or 632·27	23100 or 50·9	14625 or 32·24	224100 or 494·04	18900 or 41·66	9300 or in lb. 29·50
Total yield of latex, rubber and plugs for six months per acre per annum (in lb.)	632·27	69·4	69·5	903·74	69·1	43·8
Total yield of latex and rubber per acre per annum (in lb.)	1056·9	138·9	903·7	..	..	113·3
Average yield of latex and rubber from the two systems (in lb.)	980·3	126·1	..	..	..	..

Cost of production of rubber. If it is assumed that one man can collect one pound of latex in a day and gets for his daily wages annas twelve only then the total expenditure for the collection of 980 lb. latex would amount to Rs. 735 which would give a return of 126·1 lb. of rubber. This would mean a cost of Rs. 5-8 per lb. (8 shillings 6 pence when Rs. 13 are equivalent to £1). But according to pre-war wages the cost would be reduced to one third, i.e. it would come to Rs. 1-13 or 3 shillings per lb. This amount does not include any expenditure required for raising and maintaining *Cryptostegia* bushes and for coagulation of latex. This cost per pound when compared with that of *Hevea* rubber would appear to be exhorbitant and unless the yield of latex and rubber of *Cryptostegia grandiflora* is raised by systematic and scientific cultural investigations *Cryptostegia* may not be able to compete with *Hevea* as a normal source of vegetable rubber.

ACKNOWLEDGEMENTS

For a comparative study of the longitudinal sections of *Hevea* and *Cryptostegia* and for inferences recorded under 'Effect of tapping on regeneration and growth of shoots' we are indebted to Dr Ramanujam and his colleagues of the Botany Division of the Imperial Agricultural Research Institute. Our thanks are also due to Capt. E. P. Hosken of the Directorate of Rubber for the observations on the yield of latex, rubber and plugs carried out at Okhla. We further offer our thanks to Mr J. P. Anderson, Controller of Rubber and Major H. R. Walden for the financial assistance during this investigation.

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PHYSICAL AND CHEMICAL PROPERTIES OF INDIAN HONEY

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(Received for publication on 22 February 1946)

HONEY is defined as the nectar and saccharine exudation of plants gathered, modified and stored in the comb of the honey bees. Besides water, the essential constituents of honey are dextrose, levulose and sucrose in small amounts together with lesser quantities of mineral matter, porteins, wax, pollen, and sometimes mannitol and dextrins, and nearly always appreciable amounts of various organic acids. The flavour of honey varies considerably according to its source. According to western standards genuine honey should contain not more than 25 per cent of water, 0·25 per cent of ash, and 8 per cent of sucrose. Its specific gravity should not be less than 1·412 and its weight not less than 11 lb. 12 oz. per standard gallon of 231 cubic inches at 68°F. It should contain dextrose and levulose in about equal proportions and be lævorotatory. Honey of coniferous origin, however, gives genuine dextrorotatory samples.

In India honey is mostly used for medicinal purposes and although collected under the most natural conditions, scientific and hygienic methods are not often employed for the purpose. Nor apiculture as a profitable adjunct to general agriculture and horticulture is extensively attended to. With the prospect of honey being used as a table-food, it is now, however, receiving greater attention from the Government, and honey may soon prove an important commodity in the commercial channels of trade in this country. In consequence, it is essential to decide upon a limit of different constituents, so that a suitable standard may be maintained for the composition of honey sold in the market. With this end in view, the present investigation was undertaken.

Studies by different workers [Browne, 1908 ; Daji and Kibe, 1940 ; Eckert and Allinger, 1939 ; Fraps, 1921 ; Giri 1938 ; Neufeld, 1907 ; and Schuette and Remy, 1932] have shown that there is a good deal of variation in the physical and chemical properties of honey which will be evident on a reference to the data in Table I, collated from the work of different investigators both in India and

TABLE I

Average composition of Indian and foreign honeys

Percentage of constituents	Neufeld (1907)	Browne (1908)	Eckert and Allinger (1939)	Giri (1938)	Daji and Kibe (1940)	Das and Bose (1946)	
	European honeys	Average of 100 U.S.A. honey samples	Californian honeys	Average of 12 Coorg (Indian) honey samples	Average of 6 Indian honey samples	Average of 61 Indian honey samples	Average of 6 foreign honey samples
Moisture	.. (8·30-33·59)	17·59 (12·42-26·88)	16·50 ..	19·16 (16·20-22·14)	20·10 (15·88-24·22)	19·19 (14·17-28·67)	15·22 (14·31-16·39)
Specific gravity at 15°C.	..	..	..	..	..	1·404 (1·304-1·441)	1·427 (1·417-1·433)
Ash	.. (0·02-0·68)	0·23 (0·03-0·90)	0·21 (0·02-1·14)	0·10 (0·04-0·46)	0·58 (0·21-1·06)	0·29 (0·03-1·21)	0·11 (0·06-0·16)
Acidity as percentage of formic acid.	(0·05-0·21)	0·09 (0·04-0·25)	0·16 (0·07-0·45)	0·11 (0·06-0·29)	0·21 (0·13-0·30)	0·10 (0·05-0·32)	0·11 (0·07-0·15)
Reducing sugars	.. (49·59-93·96)	70·59 (59·61-79·86)	77·56 ..	74·98 (72·70-78·70)	65·21 (59·95-71·45)	70·78 (63·39-76·33)	71·37 (70·44-73·88)
Sucrose	.. (0·10-10·12)	1·98 (0-10·01)	2·53 ..	1·10 (0·29-1·04)	1·89 (0·37-3·95)	1·66 (0-5·07)	0·61 (0-1·42)
Levulose	..	40·50 ..	40·41 ..	39·30 (36·80-40·50)	36·98 (30·03-44·07)	37·95 (32·75-42·47)	36·58 (34·34-40·76)
Dextrose	..	34·02 ..	34·54 ..	35·68 (34·2-39·2)	28·23 (22·92-34·20)	32·82 (25·14-37·99)	34·74 (29·94-39·04)
Levulose / Dextrose	..	1·19 ..	1·17 ..	1·10 (1·00-1·18)	1·35 (0·89-1·92)	1·16 (0·89-1·54)	1·07 (0·88-1·39)
Dextrin	.. (0·09-9·70)	2·09 ..	.. ..	.. ..	3·13 (0-6·54)	..	..

N.B.—The figures in brackets indicates the range of percentage variation of different constituents of honey

* Appointed at this Institute for the work with the funds provided by the Agricultural Marketing Adviser to the Government of India

abroad. The data obtained by the present authors with Indian and foreign honeys and discussed later in this paper are also given for comparison.

Thus, the setting up of standards for pure honey on a well-defined basis of different component is rather difficult. A reasonable limit may, however, be fixed up for practical purposes. In order therefore to find out such limits for the important components of Indian honey it was considered necessary to collect samples of genuine honey from all over India at different seasons for examination.

The samples of honey analysed. Sixty-seven samples of honey* were analysed for the present inquiry. Of these, 61 samples were obtained from such diverse places in India as Jammu and Kashmir, the North-West Frontier Province, Punjab, Delhi, the United Provinces, the Central Provinces, Bombay, Coorg, Madras, Mysore, and Assam. The samples were collected at different seasons from 1940 to 1943. Most of the samples were either extracted or squeezed honey and sealed in tins or glass jars. A few samples which were received with honey-comb were squeezed out by means of linen before they were submitted to analysis.

Six samples of foreign honey from the United States, Australia, New Zealand, and England as sold in the local market were also obtained for comparison with the Indian samples.

Experimental

The following components of honey were determined, for which the methods of analysis followed were those of A.O.A.C. [1940]. For easy reference they are briefly described below :

Colour. The tint of honey samples was compared in a one-inch cell of the Lovibond Tintometer with the coloured glass slide obtained from the British Bee Keepers' Association. The samples which compared more or less with the light coloured side of the glass slide were termed ' Light Amber ' and those which compared with the dark side were termed ' Deep Amber '. Intermediate tint was noted as ' Amber '. Some samples were lighter than the light-coloured side of the glass slide and were termed ' Extra Light Amber ', whereas those which were darker than the deeper shade of the slide were termed ' Dark '.

Flavour. It is rather difficult to describe or measure the flavour of honey adequately, because of the variation in the preferences of different individuals. The samples which gave characteristic flavour of honey were termed ' Aromatic ', while those which had cooked or charred smell, were termed ' Smoky ' or ' Charred '. The samples which had no such smell as above were described as, having ' Nil ' flavour.

Besides colour and flavour granulation was also noted.

Diastatic activity. Ten cubic centimeters of honey solution (1 : 2) mixed with 1 c.c. of 1 per cent starch solution were digested at 45°C. for an hour. The solution giving olive green or brown coloration with iodine solution indicated positive diastatic activity, whereas blue colour meant negative diastatic activity.

Fiehe's Test. Ten cubic centimeters of honey solution (1 : 1) were extracted with 5 c.c. of sulphuric ether. Of the clear ether extract 2 c.c. were treated with a large drop of a recently prepared 1 per cent resorcinol solution in hydrochloric acid (sp. gr. 1·18 to 1·19). No coloration of even yellow to salmon shades indicated the absence of commercial invert sugar, whereas a cherry-red colour appearing within a minute indicated the presence of commercial sugar. It has been reported that in the manufacture of invert sugar commercially, the invert sugar produced is contaminated with a small amount of furfurol or its derivatives. The detection of these substances forms the basis of this test for the presence of commercial invert sugar in honey.

Moisture. This was determined by drying a known weight of the sample at 70°C. under vacuum to a constant weight.

Specific gravity at 15°C. This was determined by means of a specific gravity bottle fitted with a theromometer.

Acidity. A known weight of honey after diluting with sufficient water was titrated with N/10 NaOH solution, using phenolphthalein as indicator.

Total reducing sugars. These were estimated volumetrically using Soxhlet's modification of Fehling's solution.

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* These samples were collected through the Agricultural Marketing Adviser to Government of India to whom our thanks are due

Sucrose. This was calculated from the reducing sugars before and after inversion.

Levulose. It was determined from constant polarimetric readings at 20°C. and 87°C.

Dextrose. The amount of dextrose was obtained by subtracting the amount of levulose from that of total reducing sugar before inversion.

Ash. A known weight of honey was ignited in a weighed platinum basin at a temperature not above dull redness until white ash was obtained.

Presentation of results

The maximum and minimum as well as the mean values of the various constituents of honey collected from the different regions of India and abroad are shown in Table II. From regions like Delhi, the Central Provinces, Bombay, Assam, and the North-West Frontier Province the number of samples were rather small for the purpose of grade specifications.

Discussion of results

Colour. The colour of honey ranged from extra light amber to very dark and could be observed only in a general way in the absence of P fund colour grader (*U.S. Dept. Agri. Cir.* No. 24, 1933). It is well known that the colour of honey darkens on storage. In spite of long storage, however, certain samples maintained excellent colour, whereas others turned deep amber, or very dark. There was apparently no correlation between total ash content and colour.

It is probable that salts such as those of iron, copper, and manganese may account for the shades of colour. In fact, it was observed that the honey samples having deep colour always yielded either brownish or greenish ash containing appreciable amounts of iron, copper, and manganese, whereas the ashes obtained from light-coloured honey samples were always snow-white and had comparatively little of these elements. This is supported by the observations of Scheutte and Remy [1932], Giri [1938], and Daji and Kibe [1940] who have shown that there is a relationship between the degree of pigmentation and the quantity of mineral matter, notably manganse and copper, present in honey.

Flavour. The exact nature of the substances causing flavour is not fully understood. The flavour of the majority of samples was typical of honey. In some cases, the flavour was not aromatic. It is very likely that the smell of flowers from which the nectar is collected has some influence on flavour in honey, but when the nectar is collected from various kinds of flowers, flavour may be an integration of these aroma.

Diastatic activity. Honey, if not heated to a temperature more than 50°C., exhibits diastatic activity. Here, out of 67 samples, 55 possessed this property and 12 samples failed to show this, the reason for which is not clearly understood.

Fiehe's Test. No samples gave positive reaction with Fiehe's reagent, indicating the absence of commercial invert sugar in them.

Moisture. The moisture in the Indian honey samples analysed ranged from 14·17 to 26·67 per cent and the average of all the Indian samples came to 19·19 per cent ; 24 out of 61 Indian samples contained more than 20 per cent of moisture.

Well-matured honey from capped combs generally contains about 16 per cent of moisture. If it is, however, ill matured or exposed to humid weather, the moisture content may go up. On the contrary, if the place is dry, the moisture content may go down as well. As for instance, the average of three honey samples from Delhi which is a dry place, was 14·39 per cent, none exceeding 14·53, whereas the average of three honey samples from Assam which is a wet area, was 27·12 per cent, none falling below 25·09 per cent.

Honey, if allowed to contain more than 20 per cent of moisture, suffers from a serious drawback. It is then susceptible to fermentation by sugar-tolerant yeasts and bacteria. Utmost care must, therefore, be taken, while gathering honey, to guard against its undue exposure to air, especially in humid regions.

TABLE II

The minimum and maximum as well as mean values of different components of honey samples from different regions of India and other countries

Place	No. of samples analysed	Percentage of moisture	Specific gravity at 15°C.	Percentage of ash	Acidity as percentage of formic acid	Percentage of total reducing sugars	Percentage of sucrose	Percentage of levulose	Percentage of dextrose	Levulose : Dextrose Ratio
Jammu and Kashmir	7	18·93 (15·89-20·63)	1·421 (1·410-1·431)	0·13 (0·07-0·29)	0·08 (0·05-0·13)	72·42 (71·70-73·01)	0·96 (0·00-4·05)	38·47 (36·53-40·51)	33·92 (31·36-37·29)	1·14 (0·98-1·29)
N.W.F.P.	1	17·17	1·421	0·31	0·05	73·28	1·62	40·19	33·09	1·21
Punjab	7	17·85 (14·25-23·85)	1·414 (1·387-1·432)	0·20 (0·03-0·47)	0·09 (0·05-0·13)	69·81 (67·30-73·28)	2·51 (0·00-4·51)	36·08 (33·69-37·91)	33·73 (30·86-37·99)	1·09 (0·89-1·26)
Delhi	3	14·39 (14·17-14·53)	1·437 (1·435-1·441)	0·44 (0·22-0·58)	0·12 (0·09-0·14)	73·89 (72·68-76·33)	6·13 (2·43-3·55)	37·67 (36·42-39·57)	36·28 (35·83-36·76)	1·04 (1·00-1·08)
U.P.	10	18·41 (14·51-21·97)	1·414 (1·401-1·434)	0·64 (0·08-1·03)	0·11 (0·07-0·15)	69·17 (66·28-71·70)	1·31 (0·00-2·80)	37·39 (33·44-41·60)	31·77 (27·99-35·27)	1·18 (0·95-1·44)
C.P.	2	15·29 (14·29-16·29)	1·428 (1·419-1·436)	0·31 (0·24-0·38)	0·12 (0·09-0·14)	70·52 (69·28-71·75)	2·66 (2·25-3·06)	38·43 (37·11-39·75)	32·09 (32·00-32·17)	1·20 (1·15-1·24)
Bombay	2	19·09 (18·92-19·25)	1·414 (1·410-1·417)	0·27 (0·24-0·29)	0·07 (0·06-0·08)	71·65 (71·08-72·21)	1·30 (1·18-1·42)	39·15 (39·07-39·23)	32·50 (32·01-32·98)	1·20 (1·18-1·22)
Coorg	8	21·37 (20·16-24·14)	1·380 (1·352-1·399)	0·14 (0·05-0·21)	0·10 (0·06-0·14)	70·90 (68·23-74·10)	0·46 (0·00-1·43)	38·58 (36·43-41·87)	32·19 (27·29-34·86)	1·21 (1·09-1·53)
Madras	12	19·95 (16·63-26·88)	1·400 (1·354-1·417)	0·43 (0·21-1·21)	0·14 (0·05-0·32)	68·65 (63·89-74·96)	1·78 (0·26-5·07)	36·93 (32·75-41·44)	31·74 (25·14-36·54)	1·18 (0·95-1·54)
Mysore	6	21·49 (18·87-24·10)	1·396 (1·359-1·415)	0·13 (0·10-0·17)	0·11 (0·06-0·17)	70·96 (69·66-73·52)	1·51 (0·00-3·79)	39·26 (36·71-42·47)	31·67 (27·70-35·25)	1·23 (1·08-1·42)
Assam	3	27·12 (25·09-28·67)	1·323 (1·304-1·353)	0·14 (0·10-0·19)	0·12 (0·09-0·15)	67·32 (66·39-69·18)	1·04 (0·41-1·41)	35·34 (34·27-36·01)	31·99 (30·54-33·17)	1·10 (1·05-1·17)
All Indian samples	61	19·19 (14·17-28·67)	1·404 (1·304-1·441)	0·29 (0·03-1·21)	0·10 (0·05-0·32)	70·78 (63·89-76·33)	1·66 (0·00-5·07)	37·95 (32·75-42·47)	32·82 (25·14-37·99)	1·16 (0·89-1·54)
Foreign	6	15·22 (14·31-16·39)	1·427 (1·417-1·433)	0·11 (0·06-0·16)	0·11 (0·07-0·15)	71·37 (70·44-73·38)	0·61 (0·00-1·42)	36·58 (34·34-40·76)	34·74 (29·94-39·04)	1·07 (0·88-1·39)
American (Browne)	100	17·59 (12·42-26·88)	.. ..	0·23 (0·03-0·90)	0·09 (0·04-0·25)	70·59 (59·61-79·86)	1·98 (0·00-10·01)	40·50	34·02	1·19
California (Eckert and Allinger)		16·50	..	0·21 (0·02-1·14)	0·16 (0·07-0·45)	77·53	2·53	40·41	34·54	1·17

N.B. The figures in brackets indicate the minimum and maximum percentage variation of the different constituents of honey.

Honey with less tha 20 per cent of moisture is less inconvenient for table use, whereas samples with 20 to 25 per cent of moisture will spread quickly on bread. If 20 per cent is fixed as the upper limit of moisture, many honey samples will be left out. Therefore, 22 per cent seems to be convenient as the upper limit of moisture at present when scientific methods are rarely used for gathering honey.

Density. Density of all Indian honey samples varied from 1·304 to 1·441 and the average was 1·404.

Acidity. Acidity, expressed as formic acid, varied from 0·05 to 0·32 per cent and the average was 0·10.

Total reducing sugars. These varied widely from 63·89 to 76·33 per cent and the average worked out to be 70·78 per cent.

Levulose and dextrose. Levulose varied from 32·75 to 42·47 per cent and the mean was 37·95 per cent, whereas dextrose varied from 25·14 to 37·99 per cent and the mean was 32·82 per cent.

As in the case of reducing sugars, levulose : dextrose ratio varied from 0·89 to as high as 1·54 and the mean was 1·16. In most cases, however, the ratio was near about 1·1.

Granulation. An increase of the levulose content, expressed as levulose : dextrose ratio, tends to retard granulation, as has been noted by Browne [1908], and Eckert and Allinger [1939]. Thus levulose : dextrose ratio less than unity facilitates the formation of granulation in many cases. Out of the six cases with levulose : dextrose ratio less than 1·0, two samples showed no tendency to granulation, whereas some crystalline honey samples showed this ratio to be 1·0 and its near approximation. It should, however, be noted that the honey samples with high levulose : dextrose ratio were always in the liquid state. Samples from Coorg appeared to be particularly crystalline. Giri [1938] also made similar observations. Local conditions and flora, etc. may have some influence on granulation.

Sucrose. Sucrose varied from nil to 5·07 per cent and the mean was 1·66 per cent. The sucrose content of the samples analysed here is rather low, much lower than the limit of 8 per cent adopted for honeys in America. If 5 per cent is kept as the limit of sucrose, it is very likely to cover almost all Indian honeys.

Ash. Ash varied within a wide range from 0·03 to 1·21 per cent. Many of the samples exceeded the legal limit of 0·25 per cent allowed for honeys in America.

A few samples had very high ash contents. Of these, one sample was known to be gathered from honey dew. Taking most of the other samples, more or less free from contamination, it is proposed to fix 0·75 per cent as the upper limit of ash.

From Table II it is evident that the variation and the mean of different components of Indian honey samples compare favourably with those of the foreign samples with but a few slight exceptions in the case of samples collected from extremely dry and wet places.

From the results of analysis it is obvious that the fixation of grade specifications is not so easy for honey as in the case of the other agricultural produce [1937]. It is, however, possible to set up certain reasonable limits for some of the major components of honey as follows :

1. Colour should be within the range from extra light amber to deep amber.
2. Flavour should be characteristic of honey.
3. Honey should possess diastatic activity.
4. Honey should give negative reaction with Fiehe's reagents.
5. Honey should not contain more than 22 per cent of moisture.
6. Specific gravity at 15°C. should not be less than 1·350.
7. Honey should not contain more than 5 per cent of sucrose.
8. Honey should not have more than 0·75 per cent of ash.
9. Acidity of honey in terms of formic acid should not exceed 0·30 per cent.

The composition of honey has thus been shown to vary somewhat with the place of origin from which it has been collected. This may necessitate a certain amount of flexibility in the specification. For this purpose the values given in Table II may be referred to if the place of collection of honey is known.

SUMMARY

Studies with 67 samples of honey, of which 61 samples were collected from different parts of India at different seasons, show that they differ considerably so far as their physical and chemical properties are concerned. Six samples were obtained from foreign countries.

The analysis of all the Indian samples indicated the following average components in percentages of the total: moisture 19·19; specific gravity at 15°C. 1·404; acidity in terms of formic acid 0·10; total reducing sugars 70·78; sucrose 1·66; levulose 37·95; dextrose 32·82; levulose : dextrose ratio 1·16; and ash 0·29.

The variation and the mean of different components of Indian honey compare favourably with those of the foreign samples, indicating the genuineness of the honey samples examined both here in India and abroad.

Attempts have been made to set up certain reasonable limits regarding the physical and chemical properties of honey samples on a regional as well as on all-India basis, thus suggesting grade specifications for 11 regions and India as a whole.

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TAMARIND-SEED PECTIN

By T. P. GHOSE (Retired) and S. KRISHNA, Forest Research Institute, Dehra Dun

(Received for publication on 3 June 1946)

IN a recent issue of this journal, Rajnarain and Dutt [1945] have stated that tamarind-seed kernels contain starch, and not pectin as reported by us [Ghose and Krishna, 1942]. The authors have drawn this conclusion from experiments which, to say the least, are elementary and do not stand any critical scrutiny. Since the seeds do not contain any starch, it is necessary to correct the wrong impression which their report might convey, particularly at a time like the present, when the country is threatened with a serious famine. The claim that the seeds contain starch to an extent of 65 per cent might mislead the public to using the kernels as food in place of cereals, especially when four million maunds of these are availale annually in India. It is true that in times of scarcity people in South India have resorted to eating the kernels, but there are no data to show what effect they had on the people, nor are we aware of any scientific investigations on the nutritional value of the seeds. In the absence of information on these aspects, it would be unwise to suggest that they offer 'a very important staple food comparing favourably in food value with wheat and maize'. To recommend the use of the pectin in the manufacture of jams and jellies is a different matter, since in these forms only small quantities (1/10 oz. of pectin will yield about 8 oz. of jelly) will be consumed.

The tamarind seed product sets to a firm jelly in the presence of appropriate amounts of sugar and acid, and, in fact, it forms such firm jellies that a sample prepared in 1942 is still standing without much loss of strength. Though this fact has been brought to the notice of Dr Dutt (one of the authors) through private communication, he does not hesitate to make a mis-statement that the

jellies remain firm for a month only. Further, he brings this as a support to his contention that the tamarind-seed product is a starch. It is well known that starches, as a rule, do not form firm jellies under the same conditions as pectins do.

Though Rajnarain and Dutt's paper is dated 28 March, 1945, it has been made public in May 1946 through the August, 1945, issue of this journal. During this period several notes on the chemistry of tamarind-seed product have appeared from two sets of workers, besides ourselves [Ghose and Krishna, 1945 ; Nanji, Savur and Sreenivasan, 1945 ; Damodaran and Rangachari, 1945 ; Savur and Sreenivasan, 1946], and none of them has claimed the material to be a starch. They are all agreed that the pectin in the tamarind-seed kernel is not of the same class as that obtained from fruits, inasmuch as its constituent carbohydrate is not built on galacturonic-acid molecule. In physical properties, however, it shares with fruit pectins the most important property of setting into a firm gel with appropriate amounts of sugar and acid. It is on account of this property, which is the characteristic of all pectins irrespective of their chemical nature, that tamarind-seed product has been regarded as pectin [Rao and Krishna, 1946]. Investigations have shown that it is a carbohydrate which on hydrolysis with mineral acids yields xylose, glucose and galactose. It is surprizing that Rajnarain and Dutt have not even cared to identify the sugars formed as a result of the acid hydrolysis, and this simple experiment would have convinced them that the substance is after all not a starch.

It is unfortunate that the authors should have permitted the article to be printed without first checking up their findings in view of the several notes that have appeared during the interval between the date of dispatch and that of the publication. The data on which they have based their conclusion have been fully dealt with in our article which is already in press for May, 1946, issue of the *Journal of Scientific and Industrial Research* [Ghose, Krishna and Rao, 1946] and, hence, need no recapitulation here. Two points, however, require mention in this note. One concerns the colour developed by the tamarind-seed pectin with iodine on which Rajnarain and Dutt lay particular emphasis. It is common knowledge that, besides starch, other plant products are also stained blue or bluish with iodine. For example, agar-agar itself produces a bluish-violet colour with this reagent. A careful examination of the behaviour of the tamarind-seed product with iodine clearly reveals that the behaviour is not similar to that of starch. When treated with a drop of a dilute solution of iodine, starch gets blue-coloured ; under the same conditions the tamarind-seed product does not develop any specific colour. When N/10 iodine solution is added in drops to a dilute aqueous solution of the product (0·5 per cent), a greenish-yellow colour initially appears at the place of contact, but this changes to yellow on shaking. On further addition of iodine solution the following sequence of colour-changes takes place : orange, dirty brown, greenish brown and greenish blue. The blue colour, however, gets discharged on the addition of water. With concentrated solutions of the substance (1 per cent or over) a greenish-blue gel appears at the final stage. The greenish-blue gel also, on dilution with water, changes to an orange-yellow solution. Even the microscopic examination of an iodine-treated section of the seed kernel, as reported by Rajnarain and Dutt, is cursory and defective. Our investigations show that the thickened cell walls alone are stained blue, while the rest of the cell or its contents are not. The blue stain of the cell wall too is very easily washed off by the addition of a couple of drops of water. On the other hand, the blue colour developed by starch on the addition of iodine does not disappear under the same conditions. Further, the form of the thickenings of the cell wall cannot be mistaken for starch granules, even by a casual observer.

The second point relates to the occurrence of starch in the seeds and Rajnarain and Dutt have made a learned but an amusing statement that 'A seed without starch is like an animal without protein, definitely unthinkable............and there is no seed known which is free from starch'. It may be pointed out to them that (1) betel nut (*Areca catechu* Linn.), (2) date-palm seed (*Phœnix dactylifera* Linn.), (3) carob-bean seed (*Ceratonia siliqua* Linn.), and (4) S. American ivory nut (*Phytelephas macrocarpa* Riuz and Pav.) are some of the notable examples of seeds which do not contain starch.

It is thus clear that the assumptions and observations of Rajnarain and Dutt are defective and erroneous, and their conclusion baseless and misleading. It can be definitely stated that the tamarind seeds do not contain starch.

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REVIEW

A Note-Book of Tropical Agriculture

Compiled by R. Cecil Wood

(The Imperial College of Tropical Agriculture, Trinidad, pp. 136, 10*s*. 6*d*.)

THIS is a very important and useful book to agriculturists in general. Information on all conceivable aspects of agriculture has been compiled in the book ; elaborate tables and illustrative diagrams enhance its value. The book opens with a consideration of weights and measures ; there is in this chapter a very convenient table for converting one measure into another, e.g. pounds of water into cubic inches, cubic feet into gallons, etc. Then there is a chapter on surveying and mensuration followed by one on building and roads. Machinery and implements form the subject matter of another chapter and the problems of labour, soils and manures are successfully discussed in a practical manner. Various particulars regarding cereals, pulses, root crops, vegetables, oil seeds, fibres, condiments, sugar, rubbers, beverages, oil palms, fruits, etc. have been noted in the chapter entitled Crops. The next chapter is concerned with livestock management, feeding, breeding, rearing, etc. of different animals generally associated with agriculture including a list of medicinal substances and instruments which should always be at hand. The subject of dairy is appropriately dealt with after that of livestock management. A large number of diverse recipes has been listed which would indeed be considered helpful from many points of view. There is also a chapter devoted to statistics. The book concludes with a list of institutions of service to agriculturists in the tropics.

The book is a handy one, strongly bound to withstand rough handling and is to be regarded as a vade-macum to all agriculturists. The fact that a third edition, has been called forth testifies to the existence of a great demand for the book .—U.N.C.

FOURTH INTERNATIONAL CONGRESS FOR MICROBIOLOGY

NEWS has been received at the office of the Indian National Committee of the International Association of Microbiologists that the Fourth International Congress for Microbiology will be held at Copenhagen, Denmark, from July 20-26, 1947. The business of the Congress will be conducted through nine sections.

The office of the Fourth International Congress is located at Kommunehospitalet, Copenhagen, Denmark. The office of the Honorary Secretary, Indian National Committee (Dr A. C. Ukil), is located at the All India Institute of Hygiene and Public health, 110, Chittaranjan Avenue, Calcutta, from whom further information on the subject can be obtained.

For the information of those who will contribute papers, it is stated that a summary not exceeding 200 words should be in the hands of the General Secretary of the Congress at Copenhagen not later than the 1st January, 1947.

MGIPC—M—III-1-6—21-7-47—600.

IMPERIAL AGRICULTURAL BUREAUX

This organization formed by the Governments of the British Commonwealth provides up-to-date information in the form of abstracting and reviewing journals, technical communications and bibliographies on all aspects of science and practice as applied to agriculture, horticulture and forestry.

JOURNALS.

The following list comprises journals and other periodical publications. Subscription rates are quoted after each ; in certain cases (journal marked with an asterisk) a 20 per cent deduction is made for subscribers in the British Commonwealth who send their subscriptions direct and not through a bookseller.

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Review of Applied Entomology (Series A)	1	10
Review of Applied Entomology (Series B)	0	15
Review of Applied Mycology ..	1	10
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Veterinary Bulletin	2	0
Index Veterinarius	5	0
Nutrition Abstracts and Reviews	2	2
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*Herbage Abstracts	1	5
*Horticultural Abstracts ..	1	5
*Animal Breeding Abstracts ..	1	5
Helminthological Abstracts ..	1	10
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Dietary Deficiencies and Energy Metabolism	0	1	0
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Forest Tree Breeding and Genetics	0	5	0
The Use of Aerial Survey in Forestry and Agriculture	0	4	0
The Use and Misuse of Shrubs and Trees as Fodder	0	9	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1940-44 ..	1	10	0
Chemical Composition of Plants as an Index to their Nutritional Status ..	0	7	6
Fruit Fall and its Control by Synthetic Growth Substances	0	3	6

All correspondence regarding above journals and other publications may be addressed in the first instance to :—

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The Editorial Committee, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Imperial Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

Instructions to Authors

Articles intended for THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'Original not seen'.

Sources of information should be specifically acknowledged.

As the format of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{4}$ in. $\times$ $9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. $\times$ 8 in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Imperial Council of Agricultural Research, New Delhi.